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THESIS

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A COST OF QUALITY ANALYSIS OF THE
REPAIR DIVISION, MARINE CORPS
LOGISTICS BASE, ALBANY, GEORGIA

by

James A. Gray

December 1994

Thesis Co-Advisors: J. San Miguel
L. Wargo

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The pursuit of quality through quality assurance/control programs has been augmented in the recent past by implementing an organization-wide Total Quality Leadership (TQL) program at the Repair Division, Marine Corps Logistics Base, Albany, Georgia. Most TQL concepts have been successfully integrated into the culture of the Repair Division. One concept yet to be integrated deals with capturing the costs related to achieving quality. This TQL concept known as "Cost of Quality" is the subject of this thesis.

This study evaluates the TQL program, quality control program, and the cost accounting systems to determine if implementing a quality cost measurement system would provide benefits for better managing quality related costs. From this evaluation, a model of the Repair Division's cost of quality was derived. Also outlined in the study were procedures which guide the implementation of a quality cost measurement system.

The analysis revealed that the implementation of a quality cost measurement system would be a beneficial tool for management. This system would allow management to plan and control the allocation of funds used to achieve goals related to quality. The need to improve the cost accounting systems and better tracking of detailed production costs are recommended.

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A COST OF QUALITY ANALYSIS OF THE REPAIR DIVISION, MARINE CORPS LOGISTICS BASE, ALBANY, GEORGIA

by

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B.B.A., Memphis State University, 1989

Submitted in partial fulfillment
of the requirements for the degree of

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ABSTRACT

The pursuit of quality through quality assurance/control programs has been augmented in the recent past by implementing an organization-wide Total Quality Leadership (TQL) program at the Repair Division, Marine Corps Logistics Base, Albany, Georgia. Most TQL concepts have been successfully integrated into the culture of the Repair Division. One concept yet to be integrated deals with capturing the costs related to achieving quality. This TQL concept known as "Cost of Quality" is the subject of this thesis.

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TABLE OF CONTENTS

I. INTRODUCTION

A. PURPOSE

This thesis analyzes the Cost of Quality (COQ) element of a successful Total Quality Leadership (TQL) program by presenting a conceptual model. This model represents those costs which have been determined to be associated with the efforts of the Repair Division, of the Marine Corps Logistics Base, Albany, Georgia, to achieve quality. This model is known as the "Cost of Quality Model."

B. OBJECTIVE

The cost of quality model is provided as a management tool to provide a comprehensive approach to the cost areas to be considered when implementing a quality cost system. The model presents a picture of the significance of quality related costs using actual data from the records of the Depot Maintenance Activity (DMA). This model, when modified and updated using relevant and current cost data as determined by personnel evaluating the cost of quality, will allow those making upper management decisions to further evaluate the cost effectiveness of the numerous components involved in the efforts to obtain a satisfactory level of quality in their operations and products.

C. RESEARCH QUESTIONS

1. Primary Question

Can the management of the Repair Division, a Depot Maintenance Activity, and the Marine Corps Logistics Base, Albany, Georgia, benefit from a program directed toward the identification of costs related to the pursuit of quality?

2. Secondary Questions

a. What are the mission objectives of the Repair Division, MCLB, Albany?

b. What TQL initiatives for improving quality are currently in use or have been proposed for use by the DMA?

c. Is the current cost system at the DMA adequate to properly identify and aggregate the costs associated with quality?

d. Is the model provided the only way to develop a cost of quality model for the Depot Maintenance Activity?

D. SCOPE, LIMITATIONS, AND ASSUMPTIONS

1. Scope

This thesis will focus primarily on the analysis of costs related to quality which were incurred by the Depot Maintenance Activity at Marine Corps Logistics Base, Albany, Georgia during Fiscal Year 1993. These costs related to quality will be aggregated and used to provide a conceptual model for possible further use by the management of the Depot Maintenance Activity. This study will acquaint the reader with the TQL program already implemented at the DMA, but will not go into great detail on the specifics of the TQL program. It will also provide a brief summary of the functions and significant role played by the Quality Control Branch of the Repair Division.

2. Limitations

There were two primary limitations encountered in the preparation of this thesis. The first was the lack of detail of accountability built into the current automated cost system used by the DMA. Due to this limitation broad category costs could not be broken down into more itemized cost elements.

The second limitation was the condensed period of the visit to the facility to review and observe the activities generating many of the costs related to quality. This factor resulted in a limited ability to properly assess various areas for which the current cost system failed to accumulate any costs.

3. Assumptions

This thesis assumes a degree of familiarity with the concepts of Total Quality Management/Leadership (TQL) by the reader. As part of this assumption, the reader should be acquainted with the concept that controlling quality costs plays a significant role in the proper use of TQL philosophies, techniques, and evaluation for continuous process improvement.

This thesis recognizes the efforts of the management and personnel at the Marine Corps Logistics Base, Albany, Georgia and the Depot Maintenance Activity to develop and implement a comprehensive TQL program. As part of this recognition, this study assumes that the current TQL program can be further enhanced by implementing a quality cost element which is not presently used.

E. METHODOLOGY

This study examines the quality control/assurance and TQL programs resident at the Depot Maintenance Activity, Marine Corps Logistics Bases, Albany, to determine the presence or absence of a cost of quality element in either program.

The Repair Division, the DMA for MCLB, Albany was examined because it is an autonomous division of the Marine Corps Logistics Base, with their own mission, quality programs, budget, and cost system. This division is significant to the overall mission of the Marine Corps Logistics Base because it has the responsibility of performing

repair and maintenance on combat essential equipment to a degree unobtainable by lower level repair facilities.

During an on-site visit to the Marine Corps Logistics Base, the quality assurance program, total quality leadership program, mission, and cost system of the Depot Maintenance Activity were assessed in relation to the use of cost of quality as part of the total TQL approach outlined in various publications on Total Quality Management/Leadership, and more specifically, quality costs.

As part of this visit, personnel relevant to the functions of quality control/assurance, TQL, and financial management were interviewed. During these interviews, initial data was collected or requested to begin the analysis. The data collected was limited to FY93 operations, which was the most recent operating period completed. As additional data not collected during the on-site visit was required, those original personnel were contacted to render assistance.

F. LITERATURE REVIEWED

In determining the relevance of quality costs, and the methods of implementing a cost of quality system, numerous publications relating to total quality management, quality costs, and quality costs system implementation were reviewed. Those found most prominent were references 1 through 5. Additionally, because the TQL program implemented at the Marine Corps Logistics Base, Albany, was based upon their own TQL Policy and Implementation Guide, TQL Organizational "How To" Manual, and Strategic Plan, these publications were reviewed to determine the command TQL policies and how significantly they addressed the role of quality costs in the overall TQL program.

G. ORGANIZATION OF THE THESIS

This thesis is comprised of six individual chapters. Chapter I serves to introduce the reader to the subject underlying the premise of the study. It also justifies the research, announces the primary and secondary research questions to be addressed by the study, examines the scope of the work and explains the limitations encountered by author during the research, summarizes the methodology used to conduct the research, briefly discusses the literary review, and lays out the organization of the thesis document.

Chapter II will offer background information on the DMA as part of the Marine Corps Logistics Base, Albany, Georgia and address the current quality assurance and TQL programs actively being pursued at the DMA.

In Chapter III, the general concept of Total Quality Leadership and the role of quality costs, therein, will be addressed as a formal literature review. This chapter will also discuss the conceptual framework from which the Cost of Quality model was derived.

Chapter IV will be a discussion of the methodology used to conduct the research into the thesis topic. Chapter V presents the Cost of Quality model formulated from data gathered from actual DMA activities and operations. The final conclusions and recommendations derived from the overall research process is presented as Chapter VI.

II. BACKGROUND

A. CHAPTER INTRODUCTION

This chapter contains the background material on the Repair Division, Marine Corps Logistics Base, Albany, Georgia. Section B is a brief description of the history, mission, and organizational structure of the Repair division. Section C is an overview of the TQL concepts, policies, and tools used throughout the Division and taught by the TQL Office. In Section D the Repair Division's definition of quality is presented along with TQL quality goals and program background. Section E gives a brief review of some of the tools and techniques used in the Division TQL efforts. A brief overview of the Quality Control Branch is given in Section F, and the conclusion to Chapter II is presented as Section G.

B. REPAIR DIVISION

1. History

Repair Division of the Marine Corps Logistics Base (MCLB), Albany was originally titled the Repair Branch. It was established in 1954 when the MCLB, Albany was called the Marine Corps Depot of Supplies. The current title was adopted in 1956. Repair Division, Albany falls under the cognizance the Maintenance Directorate who reports directly to the Commander, Marine Corps Logistics Bases. The Repair Division at Albany is one of two repair divisions under the charge of the Commander, Marine Corps Logistics Bases and the Maintenance Directorate. The other Repair Division is located at the Marine Corps Logistics Base, Barstow, California. Due to their growth in responsibilities and the expansion of facilities and industrial production capability over their many years of operation, the Repair Divisions are currently

referred to as Marine Corps Multi-Commodity Maintenance Centers (MC^3). [Ref. 6]

2. Mission

As the Depot Maintenance Activity (DMA) for the MCLB, Albany, the Repair Division is comparable to a major civilian corporation in many ways. It has its own organizational budget, structure, and culture, yet, the DMA is unique because it does not directly manufacture any major end items. Therefore, is not considered a "manufacturer." However, the services it does provide in the repair and maintenance of major end items, including manufacturing major component parts to replace Original Equipment Manufacturer's (OEM) parts, and fabricating specialized tools and minor repair parts, makes it more than an ordinary service organization.

Due to the uniqueness of its operations, the senior level management of the Maintenance Directorate and the DMA have taken the perspective of the customer and determined that the DMA is a "producer" as opposed to a service provider. This approach is deemed customer oriented because the customer's primary consideration is the quality of the piece of equipment it receives from the Repair Division, regardless of the item's condition when received by the Repair Division.

In providing the customer with a quality product, the Division carries out the following responsibilities assigned by its mission statement set forth in the *Marine Corps Logistics Bases Organizational Manual*:

- return unserviceable equipment to serviceable condition as long as the one-time repair cost is within limits established in applicable Marine Corps Orders;

- perform maintenance through depot level by repair, over-haul, or rebuild;

- accomplish such modification, fabrication, and assembly as directed;

- perform engineering and technical services and develop maintenance rebuild standards;

- provide technical assistance, technical inspection, and turn-around repair services for Fleet Marine Forces and Marine Corps Reserve Units;

- provide inspection, maintenance, and preservation for in-storage technical stocks;

- perform material inspection and evaluation as required;

- perform preparation for shipment of material which requires the peculiar services of the Depot Maintenance Activity (DMA);

- perform quality control services;

- accomplish test, repair, and calibration of electronic, radiac, mechanical test equipment;

- provide maintenance through depot level calibration support for other military services under Interservice Support Agreements (ISSAs);

- provide career development, technical, and on-the-job training to develop required skills and maintain proficiency levels of civilians and Marines in their technical specialties.

3. Organization of the Repair Division

The Repair Division is under the control of the Maintenance Directorate, which is the overall focal point for depot level maintenance for the Marine Corps. Figure 2.1 is an illustration of where the Maintenance Directorate falls in the organization of the MCLBs.

The Repair Division itself is physically located on 242 acres of land with 30 buildings providing more than 671,000 square feet of covered space for work and storage. There is approximately 1.5 million square feet of concrete pavement for outside work and staging of equipment. The Division is made up of seven branches which employ approximately 1,100 civilian

and military personnel. These personnel represent 77 different trade skills used to perform maintenance and repair on some 1,600 types of ground combat and combat support equipment in the Marine Corps inventory. [Ref. 7 and 8].

The seven branches that comprise the Division (Figure 2.2) are the Plans and Management Branch, the Industrial Engineering Branch, the Production Control Branch, the Quality Control Branch, the Metrology Branch, the Automatic Test Support Branch, and the Shops Branch.

a. *Plans and Management Branch*

The Plans and Management Branch is composed of the four sections of Systems and Procedures, Financial Management, Management Services, and the Business Office. These sections represent the corporate office of the Repair Division and perform operations relating to activities such as: financial planning, budgeting, and monitoring; planning, installing, and monitoring data systems; general management and administrative services; and customer service, business planning, and workload planning. [Ref. 9]

b. *Industrial Engineering Branch*

This branch has three sections: Methods and Standards, which is responsible for engineered performance standards, special tools and fixtures support, special studies in work sampling and measurement, and evaluation and approval of Beneficial Suggestions and Process Improvement Forms (PIFs); Engineering, which provides all engineering services; and Special Projects, which is responsible for providing technical assistance and engineering designs, and developing technical data packages and prototypes. [Ref. 10]

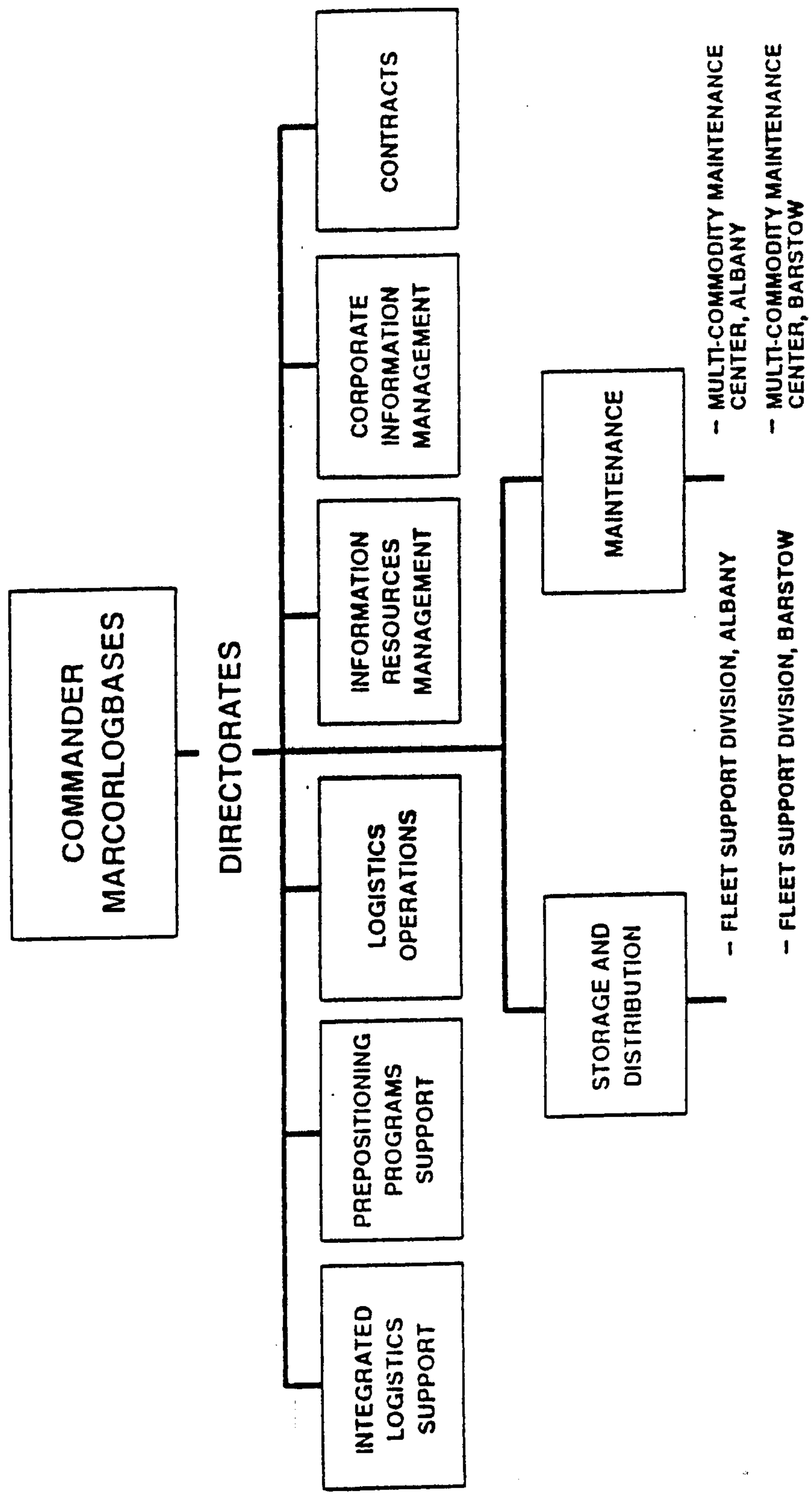

Figure 2.1. From Ref. [11].
Commander Marine Corps Logistics Bases
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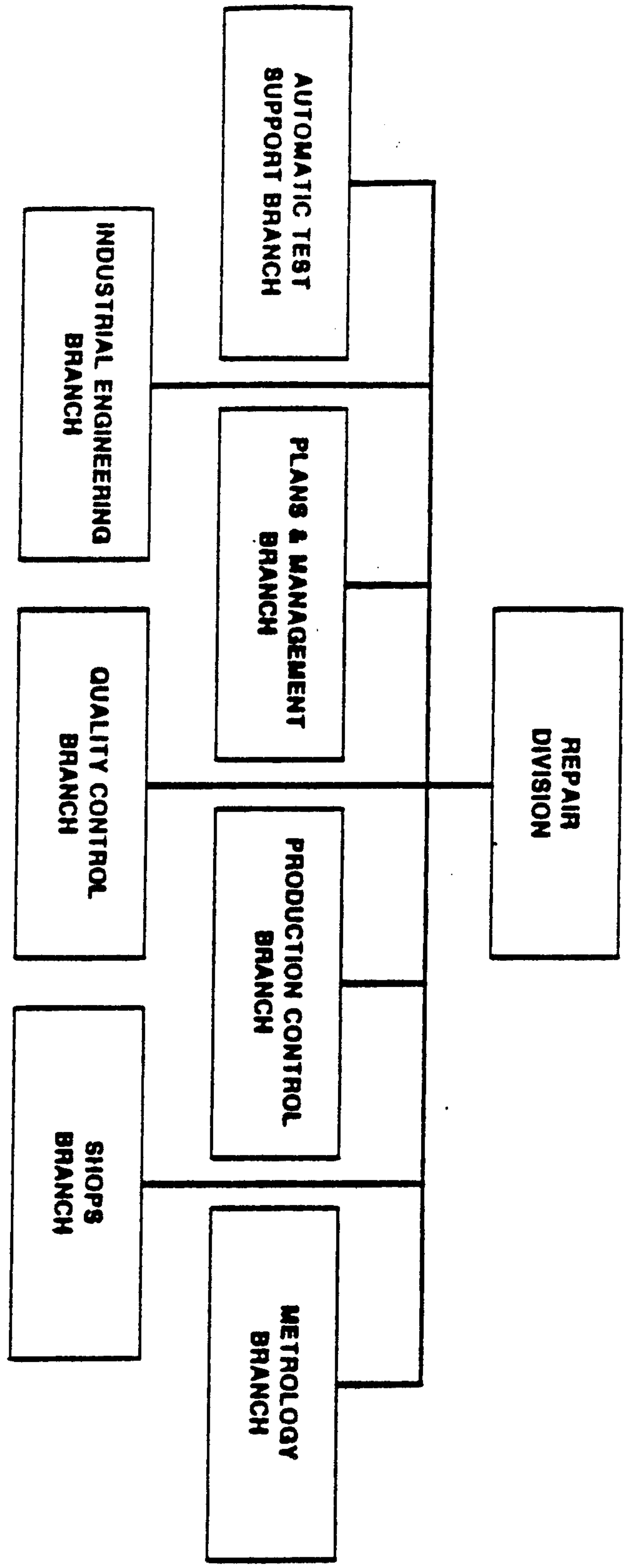

Figure 2.2. From Ref. [12].
Repair Division, MCLB Albany

c. Production Control Branch

The PC branch's three sections, Planning and Scheduling, Shops Control, and Material Control, are responsible for developing the Master Work Schedule (MWS), providing and monitoring job plans in the shops, and maintaining and providing supplies, tools, equipment, and materials necessary for production. [Ref. 13]

d. Quality Control Branch

The two sections of Quality Inspection and Quality Evaluation perform all the inspections and evaluations related to quality control for the MC^3. Along with a great number of other responsibilities, their activities include evaluations of incoming equipment for repair, determination of preservation levels to prevent further deterioration of equipment, investigation of quality deficiencies, recommendation or correction of quality deficiencies, and establishment and dissemination of quality standards, inspections plans, standard inspection procedures, station checklists, and defect indexes. [Ref. 14]

e. Metrology Branch

Mechanical Calibration and Repair, Electronic Calibration and Repair, and Test, Measurement, and Diagnostic Equipment (TMDE) are the sections which make up the Metrology Branch. Together these sections provide a wide range of calibration and technical support to the MC^3 and the Fleet Marine Forces (FMF). [Ref. 15]

f. Automatic Test Support Branch

The Automatic Test Support (ATSU) Branch is made up of four sections, Test Programming, Engineering Support, Marine Corps Automatic Test Equipment (ATE) Support, and Project Management. These sections have the responsibility to

provide management, design, development, and technical support and assistance for all Marine Corps ATE, Test Program Sets (TPSs), and Application Program Sets (APSs) used in the maintenance of Marine Corps weapon systems and equipment. [Ref. 16]

g. Shops Branch

This branch is responsible for all of the management and operation of the productive operations such as overhaul, repair, modification, fabrication, cleaning, painting, preservation, and testing of equipment processed through the Repair Division. The actual repair and maintenance is performed in the five Production Control Centers (PCCs); Vehicle, Ordnance, Communications and Electronics, Support, and Preservation. These five PCCs are separated into 19 Cost Work Centers (CWCs) which perform work and/or receive financial charges. [Ref. 17]

C. REPAIR DIVISION'S TQL INVOLVEMENT

The purpose of this section is to briefly acquaint the reader with some of the TQL concepts, plans, and policies which apply to or are being used by the Repair Division in their efforts to become a total quality organization. It will specifically focus on where the Division TQL guidance originates and how the Division has made this guidance part of its operating structure.

1. History of TQL in the Repair Division

Beginning in 1989, as part of the Department of Defense (DOD) initiative, "to implement Total Quality Management for continuous performance improvement at every level and in every area of responsibility," the Commander, Marine Corps Logistics Bases developed and implemented a thorough and comprehensive

TQL program. The tenets of this program are published as Base Order 5000.21 (*MCLB, Albany TQL Policy and Implementation Guide*).

Based upon the quality philosophy of Dr. W. Edwards Deming, the DOD established nine TQL principles which have a direct correlation to Deming's "Fourteen Obligations of Top Management" [Ref. 18]. The following DOD principles, adopted for use by MCLB, Albany, are from MCLB, Albany Base Order 5000.21.

a. Constancy of Purpose (Deming Point 1). Goals and objectives, identified and provided by executive management, provide focus and are realized through practicing continuous improvement and recognizing and rewarding purpose achieving behavior.

b. Continuous Process Improvement (Deming Point 5). The primary TQL objective is the continuous improvement of every aspect of this Base's work. That objective is implemented through a structured disciplined approach that incorporates training, leadership, and teamwork to improve all processes. With TQL, emphasis is placed on preventing defects through process improve- ment rather than discovering them through product inspection.

c. Customer Focus (Deming Point 11). Customer response and mission performance are the absolute tests of our effectiveness. Although MCLB, Albany customers include the FMF, other military services, other federal agencies, allied forces, and some non-governmental customers, the Base also has internal customers. A thorough understanding of the needs of all customers, internal or external, not only provides the means for assessing performance, it also helps to establish future directions and goals.

d. Process Knowledge (Deming Points 3 and 4). Process knowledge is essential for positive change. Positive change is primarily created through process improvement ideas generated by management and the work force. Management must thoroughly understand the processes which they can influence and for which they are responsible.

e. Commitment (Deming Point 2). Base executive leadership ensures strong, pervasive commitment to continuous improvement. This commitment results in cost reduction, schedule compliance, customer satisfaction, and pride in workmanship. Acting on recommendations to make positive changes demonstrates commitment to continuous improvement.

f. Top-Down Implementation (Deming Points 7 and 8). TQL will first be implemented by Base executives and flow down as a waterfall. This cascading deployment ensures that Base leaders understand, demonstrate, and can teach TQL principles and practices. This must be done at each level before full implementation of TQL to the next subordinate level can be fully achieved.

g. Total Involvement (Deming Point 14). Process improvement applies to every operation and individual on Base, because all products and services are produced through processes.

h. Teamwork (Deming Points 9 and 10). Teamwork is essential for continuous improvement. Teamwork and team structure align goals, objectives, and thought. Team activities enhance communications and cooperation, stimulate creative thought, and provide an infrastructure to support TQL practices.

i. Investment in People (Deming Points 6, 12, and 13). MCLB, Albany's largest and most valuable investment is in their people. They provide the knowledge and experience on which the Base relies. They are the most essential component in continuous process improvement. Training, team-building, and work-life enhancements are important elements in creating an environment in which their people can grow, gain experience and capabilities, and contribute to the national defense on an ever-increasing scale.

These principles are the foundation on which the Repair Division's TQL commitment is based.

2. Repair Division As Part of the MCLB TQL Structure

The MCLB, Albany *TQL Organizational "How To" Manual* specifies the TQL organizational structure (Figure 2.3) and TQL communication flow (Figure 2.4) which the Repair Division is a part of and must adhere to in carrying out their TQL initiatives. Following this guidance, the Repair Division has developed their own TQL organizational structure (Figure 2.5).

D. REPAIR DIVISION'S TQL/PERFORMANCE IMPROVEMENT PROGRAM

This section will offer information on the Repair Division's definition of "Quality," some insight of the quality goals, and how the TQL program is established and implemented throughout the organization.

1. Quality Defined

The Repair Division looks beyond the extremely detailed mission statement {subsection B.2} given by the Marine Corps Logistics Bases Organizational Manual. In simplified terms, the Division states its mission for TQL purposes to be, "To provide maintenance and maintenance related products and services

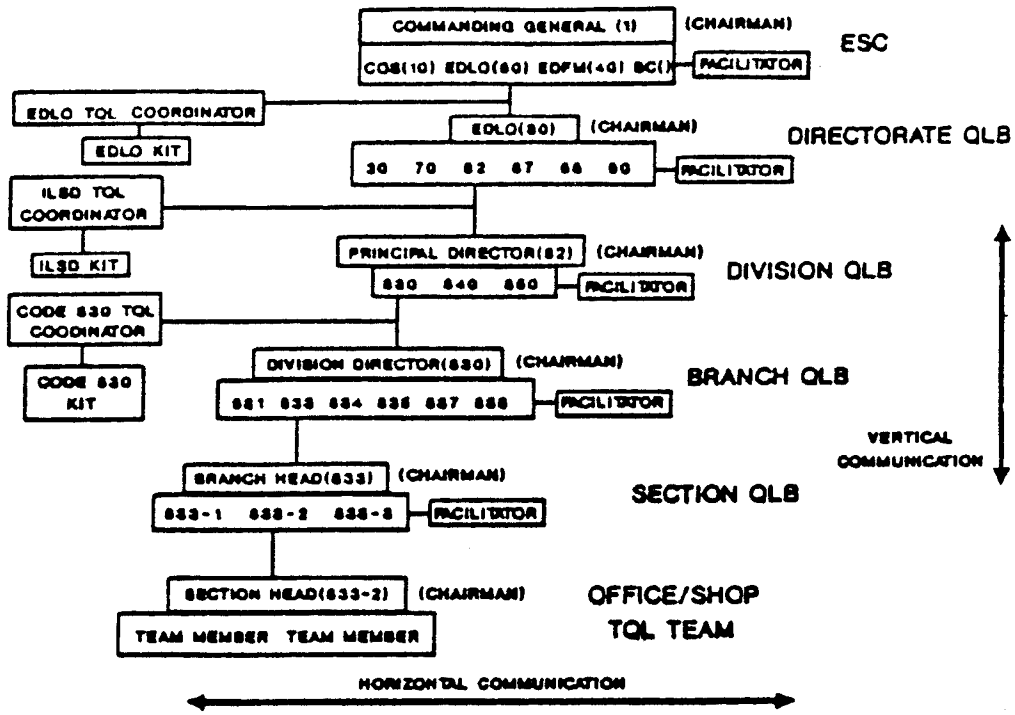

Figure 2.3. From Ref. [19].
MCLB TQL Organizational Structure

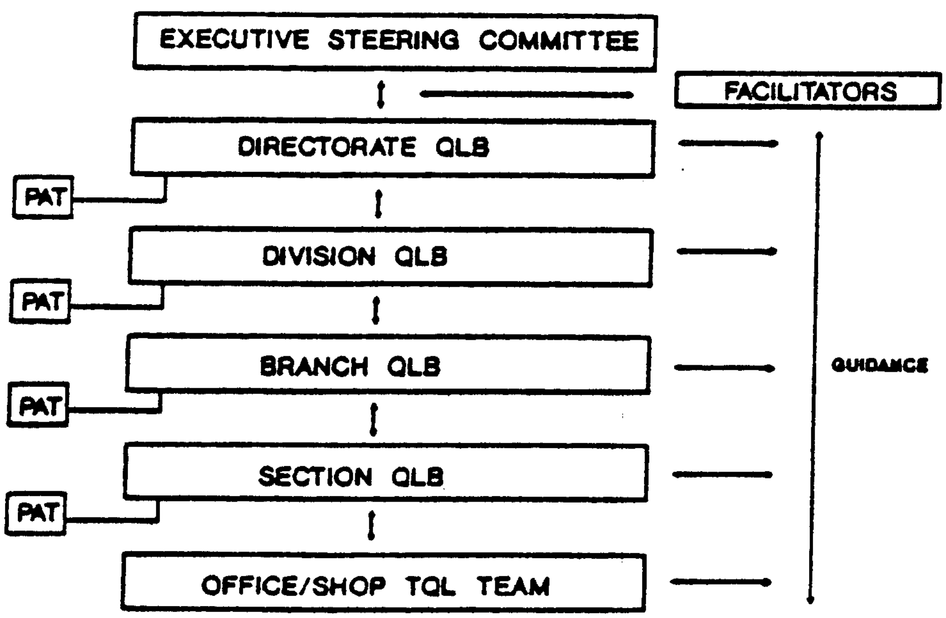

Figure 2.4. From Ref. [20].
MCLB TQL Communications Flow

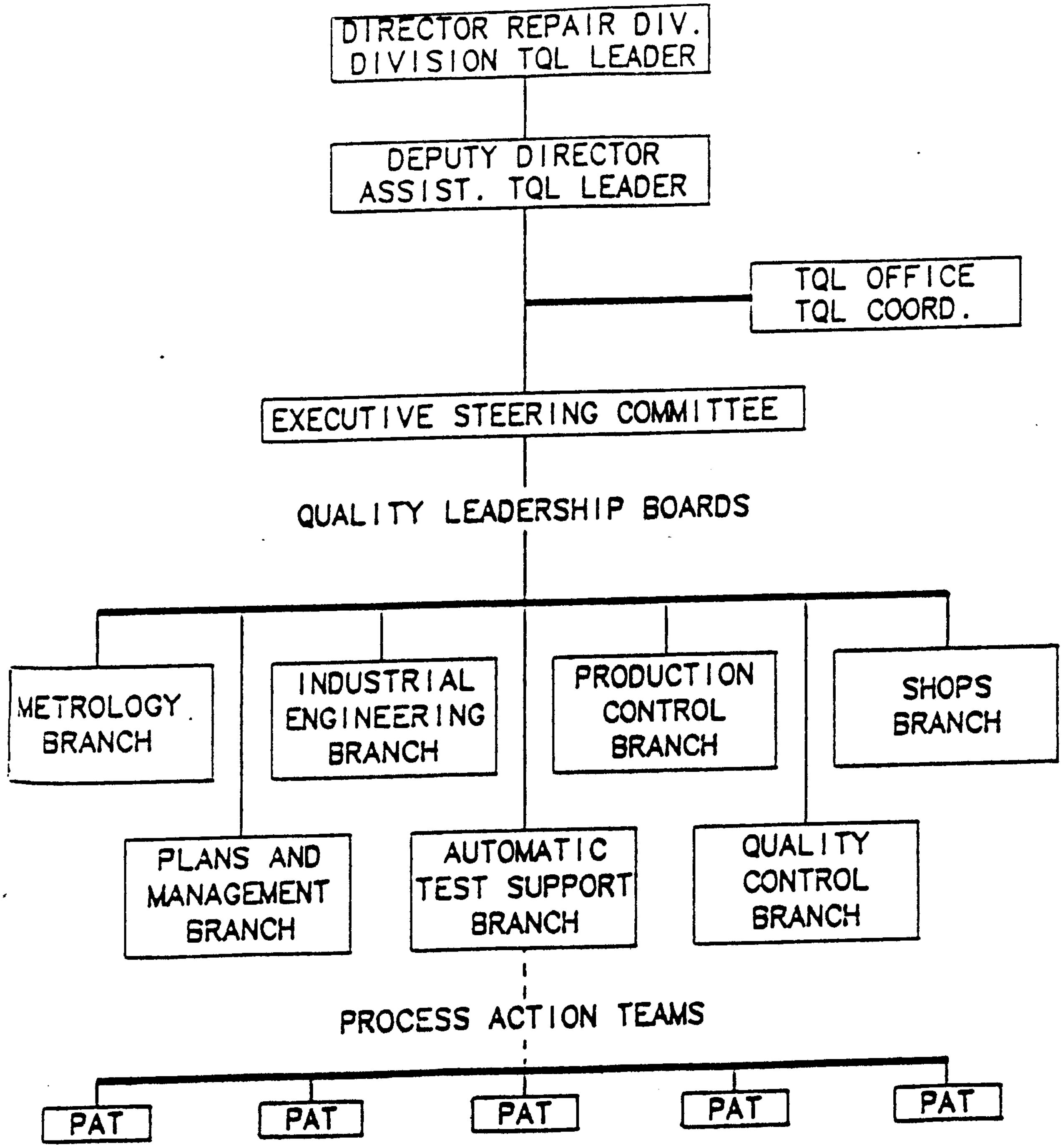

Figure 2.5. From Ref. [21].
Repair Division TQL Organizational Structure

which meet our customers' needs in cost, **quality**, and schedule." [Ref. 22] Considering this mission statement, the Division defines quality in the following manner: **Quality**: Provide products or services which meet or exceed our customers' requirements. [Ref. 23]

2. Division TQL Key Areas, Goals, and Measures

The establishment of five key areas is one way the Division attempts to fulfill its mission in relation to the TQL program. These key areas, their goals and measures, are presented to emphasize some of the areas where quality costs will later be considered.

a. Area 1: Customer Focus/Satisfaction

The emphasis in this area is to create a partnership with customers, while understanding their needs and providing high quality products and services on a consistent basis. The single goal here is to create a benefit for both the Division and customer through improved relationships.

The Division uses the following measures to gauge improvement in this area: customer service training, Product Quality Deficiency Report's (PQDRs) received from customers, Report Of Discrepancies (RODs) prepared on incoming material, PQDRs generated on incoming material, external customer concerns, average time taken to resolve customer concerns and PQDRs, and a customer service index. [Ref. 24]

b. Area 2: Human Resource Development

This area deals with the opportunities for personal and professional growth, skill development, job satisfaction, safety, recognition, and process improvement involvement offered to individuals throughout the Division. There are two goals of the efforts expended in this area. The first goal is the involvement of everyone in improving work processes, work

environment, recognition and morale. It is measured by the following: awards/recognition given/received, Process Improvement Forms (PIFs) and Management Initiatives (MIs) submitted, PIFs profiled, Beneficial Suggestions (Benny Suggs) submitted, Benny Suggs cost savings, Process Action Teams (PATs) chartered, lost time hours, total mishaps, and mishap types. [Ref. 25]

The second goal is to use education and training to increase the personal and professional development of the work-force. Success or failure in this endeavor is measured by tracking TQL training hours and cost, total training hours and cost, number of employees receiving tuition assistance, number of high school graduates employed, and number of employees with college degrees.
[Ref. 26]

c. Area 3: Organizational Streamlining

The focus in this area is to create an organization which can satisfy the needs of the customer. Another part of this focus is the desire to remain or become as flat as possible, and eliminate redundancy in functional areas. The TQL goal here is to structure an organization which eliminates waste while making the most of continuous improvement processes, teamwork, and decentralized decision making. The measures of success in this area are: cumulative cost savings, ratio of direct to indirect labor hours, labor efficiency, material efficiency, rework cost, Material Returns Program (MRP), and various measures used for other goals.
[Ref. 27]

d. Area 4: Sound Business Practices

Assurance of future survival through effective and efficient management in all aspects of business is what the Division seeks to achieve in this area. The ability to

consistently work on the right things to improve the management of cost, schedule, and quality is the primary goal of area four. Measures of goal accomplishment for this area are: Cost of Quality (COQ), schedule conformance index, cost performance, labor efficiency, direct material utilization index, cost of non-conformance index, rework hours, competition execution index, accumulated operating results (AOR), cash position, unbilled customer orders, MRP, PQDR cost avoidance, major line item defect summaries. [Ref. 28]

e. Area 5: Environmental Excellence

The core desire of area five is to set the standard for environmental excellence for DMAs throughout DOD. As an addendum to this, providing a safe, attractive, and comfortable work environment is also of primary interest. In line with setting a new standard for environmental excellence is the goal of exceeding the existing standard. The functions considered to be good measures of performance in this area are: above ground storage, mishap total and type, hazardous material management system, and lost time hours. [Ref. 29]

3. Establishing and Implementing TQL

Repair Division's TQL Office follows the seven steps of the Total Quality Management Model for performance improvement outlined in detail in BO 5000.21 as guidance for their TQL implementation efforts (see Figure 2.6). An indepth explanation of these steps is not considered relevant to the overall purpose of this study.

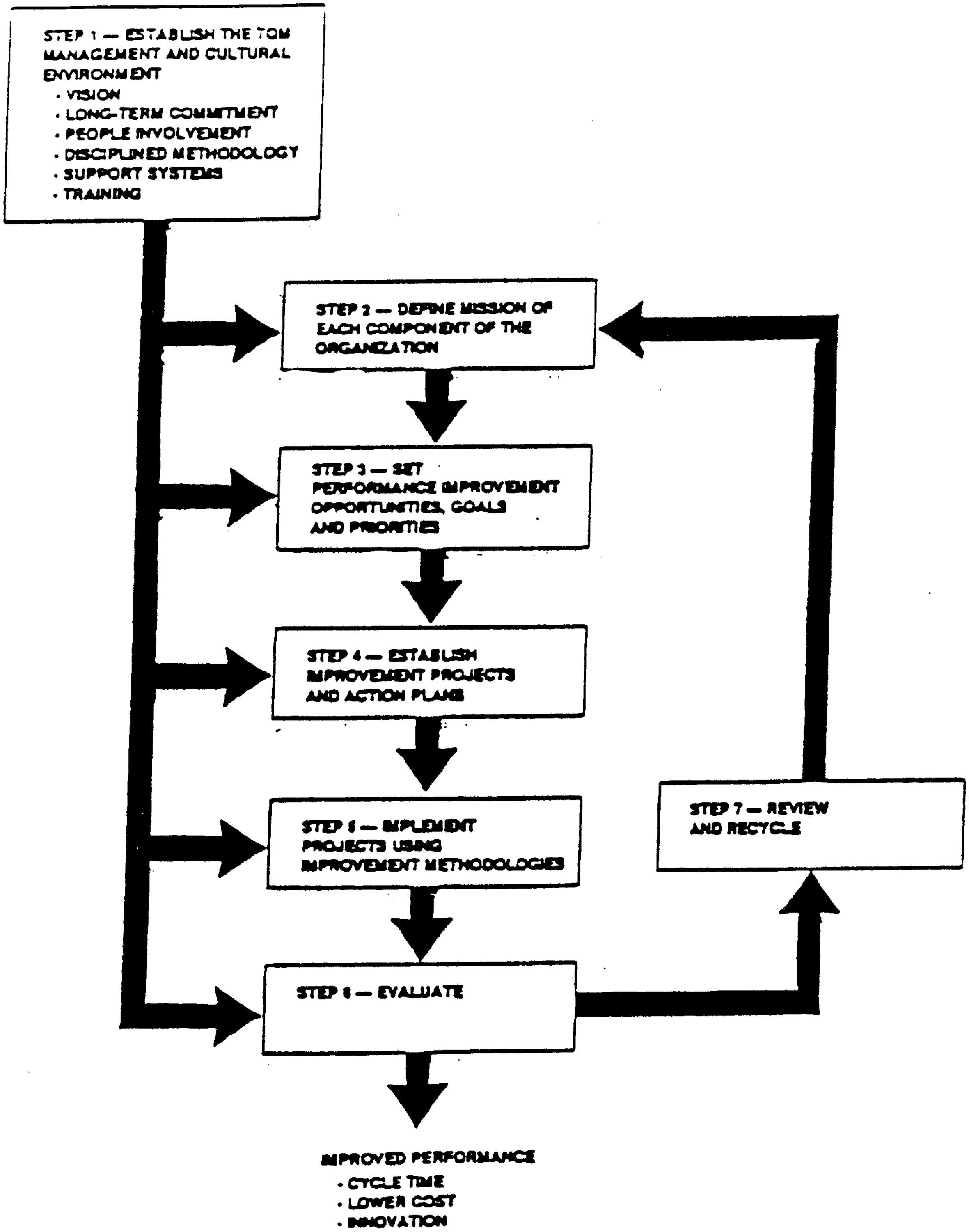

Figure 2.6. From Ref. [30].
Performance Improvement Model

E. REPAIR DIVISION'S TOOLS AND TECHNIQUES FOR TQL

This section provides information on the generic tools and techniques the Repair Division's TQL Office teaches and utilizes in their process improvement strategies/activities. The 14 tools and techniques of total quality management are: improvement in non-production functions, benchmarking, cause and effect diagrams, concurrent engineering, cost of quality, design of experiments, input/output analysis, Pareto charts, nominal group techniques, Quality Function Deployment, statistical process control, team building, time management, and work flow analysis. These tools and techniques are provided in BO 5000.21, the *Policy and Implementation Guide* as general guidance for TQL implementation throughout all levels and divisions of MCLB, Albany. The use of these generic tools and techniques in the Repair Division TQL program represents an example of one element of the effort directed toward process improvement and quality assurance.

F. QUALITY CONTROL IN REPAIR DIVISION

The Quality Control (QC) Branch of the Repair Division plays a primary role in the Division's ability to provide quality products to its customers. Given the significance of this branch, it merits a closer look. The purpose of this section is to explain more fully the responsibilities and organization of the Quality Control Branch of the Repair Division. Additionally, this section will provide information on some of the measures used to evaluate the efforts of the QC Branch.

1. Organization

There are approximately 57 people who make up the administrative, Quality Inspection, and Quality Evaluation sections of the QC Branch. [Ref. 31]

2. Responsibilities

As a branch, the three sections of QC have the following responsibilities as specified by the *MARCORLOGBASES Organizational Manual:*

- Perform the inspection and quality evaluation functions for Repair Division operation:

- perform inspection and evaluation for in-storage maintenance and preservation of equipment and materials as required;

- perform limited technical inspections for other Divisions of the Base and for other military activities as required.

- Perform annual on-site inspection of all items of Marine Corps furnished equipment reportable under the Recoverable Items Program in the possession of Marine Corps Reserve Units, and provides on-demand technical assistance.

- Provide pre-repair, in-process, and final test and inspection of equipment processed by Division shops.

- Evaluate incoming technical equipment to determine the depth of repairs necessary to return items to serviceable condition;

- provide planning data to assist in the preparation of job order for the induction of repair work;

- determine the level of preservation required to prevent further deterioration of equipment prior to induction for repair;

- investigate quality deficiencies, corrects or recommends corrective action to remedy quality deficiencies in all production areas, including tool quality, labor, and supervision;

- establish and promulgate quality standards, inspection plans, standard inspection procedures, station check lists, and defect indexes;

- establish and monitor station process control charts;

- evaluate, investigate, and recommend corrective action for in-process defects and deficiencies;

- disseminate such reports as required to assure a quality product;

- and provide technical assistance to other branches of the Repair Division as required.

As is evident by the detailed list of responsibilities, the QC Branch has an enormous job covering all of the production items processed through the DMA on a continuous basis. Additionally, in light of the emphasis of TQL to improve processes, the QC Branch must continuously evaluate the manner in which the personnel in the Quality Inspection Section are used.

3. Measures of Performance

In an attempt to evaluate the effectiveness of QC Branch efforts, the staff of the Statistical Services Unit, Quality Evaluation Section, produces the *Quality Progress Report.* This report, produced twice monthly, is used to meet a requirement set by MCLB, Albany BO P4855.8 *Quality Assurance Programs.* The requirement states that the QC Branch must develop and maintain "...statistical charts and data utilizing control charting techniques, Acceptable Quality Levels (AQLs), and control limits to reflect whether the quality of the product acquired, received, stored, repaired or issued is per the established standards." [Ref. 32]

In providing the data required by BO P4855.8, the Statistical Services Unit accumulates the daily Quality Inspection Reports (QIRs) turned in by the inspectors of the Quality Inspection Section, and analyzes the information. From this data, the *Quality Progress Report* is produced. The report is subdivided into 14 parts relevant to the Repair Division operations.

a. Inspections Performed

This part of the report is a graphical representation of the total number of inspections conducted by QC Branch inspectors. In addition to this particular use of the QIRs generated by the inspectors, they are used to provide feedback to the section requesting the inspection. Personnel from these sections use the QIRs to make corrective action using TQL tools and techniques for process improvement.

b. Quality Report

This report aggregates total Cost Work Center inspections. Using this report, information can be gathered on total Work Center inspections, number of major and minor defects reported, and defect percentages. Upper control limits are supposed to be calculated from this data. However, the process for calculating them was under review at the time of this study.

c. Inspection Report

In this report, the combined number of major and minor defects provided in the Quality Report is further subdivided into major commodity items being inspected. Along with this data, the estimated time for corrective rework per defect is given.

d. Major Defects

The Repair Division uses the Military Standard 109 (MIL-STD-109) definition to define a major defect. The definition in the *Quality Progress Report* states that a major defect is a defect "...that is likely to result in failure, or to reduce materially the usability of the unit of product for its intended purpose." The major defects portion of the report provides a 12 month graphical illustration of the total major defects reported throughout the Division.

e. Major Defects Per Hundred

This portion of the report is a graph of the percentage of major defects found per one hundred inspections during a one month period. The graph covers a 12 month period.

f. Major Defects By Cost Work Center

A graph of the major defects broken down into 20 CWCs (19 CWCs in the five PCCs and one Special Projects CWC) in the Division is presented in this portion of the report.

g. Minor Defects

The definition of a minor defect given in the *Quality Progress Report* states that a minor defect is a defect "...that is not likely to reduce materially the usability of the unit of product for its intended purpose, or is a departure from established standards having little bearing on the effective use or operation of the unit." This section presents a graph of the total minor defects for the most recent 12 month period.

h. Minor Defects Per Hundred

Similar to major defects per hundred, this section of the report is a graph of the most recent 12 months' percentages of minor defects per hundred inspections.

i. Minor Defects By Cost Work Center

Here, minor defects categorized by CWC are presented graphically.

j. Defect Rate By Control Center

A graph of the gross defect rate per hundred inspections for the five Production Control Centers (PCCs) is

given in this section of the report. The five PCCs contain 19 of the CWCs in the Division.

k. Repair Division Estimated Rework Man-hours

Total estimated rework man-hours for the Division is depicted as a graph in this section.

l. Estimated Rework Man-Hours By Control Center

The estimated rework labor hours necessary to correct the recorded defects and reinspect the item are in the form of a graph in this section.

m. Nondestructive Testing (NDT) Summary Sheet

NDT Summary Sheets are provided as an abstract of the results of the nondestructive testing program for the period covered by the semi-monthly report.

n. Material Review Board (MRB) Actions

This section reports the actions taken by the MRB to promote cost effective utilization of materials, supplies, or assets containing defects. This MRB which is officially made up of the Head, QC Branch, Head, Industrial Engineering Branch, and the Senior Marine Commodity Expert, usually makes the decision to scrap, repair, or use the asset in its current condition.

o. Defect Control Limits

Although part of the BO P4855.8 requirement is to establish control limits for defect categories, the method for meeting this requirement was still under consideration as of June 1994.

G. CHAPTER CONCLUSION

This chapter has briefly presented basic information on the mission, organizational structure, and history of the Repair Division. It has also given some idea of the TQL environment of the Division by presenting a synopsis of the policies and goals on which the program is founded. Additionally, the TQL model, tools and techniques, and an examination of the Quality Control Branch were presented in this chapter.

From the perspective of the researcher, the Repair Division has implemented an extensive TQL program which enhances the efforts of the QC Branch. The researcher has made the assumption that the reader is familiar with the primary philosophies, concepts, and tools of TQL. Having made this assumption, the researcher did not present this chapter as an attempt to give an indepth education of TQL.

Chapter III will explore the theory behind the use of quality costs as a management tool and their significance in the decision making processes related to the effectiveness of Quality Control and TQL programs.

III. THE SIGNIFICANCE OF QUALITY COSTS

A. CHAPTER INTRODUCTION

Many organizations are now adopting continuous quality improvement in their products and services as their primary long range organizational objective. This objective, as discussed in Chapter II, is clearly the emphasis of the expansive TQL and quality control programs developed and implemented throughout the Marine Corps Logistics Base, Albany, and the Repair Division. The effective evaluation of performance in quality improvement requires specific and regular measurement of activities underlying the quality area. One such measurement, the "Costs of Quality (COQ)," is the focus of this entire study.

The purpose of this chapter is to provide a discussion of the relevant theory behind quality costs, and the implementation of systems to measure them. Also, the concepts behind the development of the quality cost model (to be presented in Chapter V) are discussed.

B. BACKGROUND ON QUALITY COSTS

1. Introduction to Quality Costs

Those costs referred to throughout this study are known to have many names such as: "cost of quality," "costs related to quality," "poor quality costs," or "cost of poor quality." The most widely used terminology, and that used by the military, to describe these costs is "quality costs." Although they are known by different names, these costs are basically the costs incurred by an organization in its efforts to offer a product or service which meets the needs of the customer it was supposed to satisfy. These costs include more than just the running of the quality control department. They

include such costs as those incurred internally when a production item must be scrapped due to design changes, a department head has to send a ready-for-signature document back for retyping because of typing errors, or workers are idle due to equipment failure.

An example of quality costs due to external factors is lost revenues due to a loss of customers because components were missing from a product purchased ready-for-assembly. Summarily, quality costs include any cost resulting from efforts to assure a quality product or service, and any cost resulting from the failure to deliver a quality service or product to the internal or external customer.

2. History of Quality Costs

The principle literary sources on the subject of quality costs cite Chapter I of Dr. J. M. Juran's *Quality Control Handbook*, published by McGraw-Hill in 1951, as the first place the phrase "quality costs" was used. In his tome, Dr. Juran hypothesized that the optimal level of quality is found at the point where losses due to defects are equal to the costs associated with quality assurance and control efforts. Among other early writings on quality costs is the W. J. Masser article, "The Quality Manager and Quality Costs," published in 1957, where quality costs were first put into the four categories of prevention, appraisal, internal failure, and external failure. Other early writings on the subject, such as "How to Put Quality Costs to Use," written by Harold Freeman in 1960, and the fifth chapter of *Total Quality Control*, a book written by Dr. A. V. Feigenbaum in 1961, soon followed suit and used the four categories originated by Masser.

Soon after the concept of quality costs became popular, the Department of Defense (DOD) published a document identifying the quality program requirements for DOD

contractors. This Military Specification for quality is known as MIL-Q-9858A, *Quality Program Requirements*. It became effective 16 December 1963 and has been amended twice, 7 August 1981 and 8 March 1985. This document obligates DoD contractors to establish a quality program to assure compliance with specific contracts. Section 3.6 of MIL-Q-9858A deals with the subject of quality costs as they would apply to the Repair Division.

Section 3.6, entitled, "Costs Related to Quality," specifically states:

> The contractor shall maintain and use quality cost data as a management element of the quality program. These data shall serve the purpose of identifying the cost of both the prevention and correction of nonconforming supplies (e.g., labor and material involved in material spoilage caused by defective work, correction of defective work and for quality control exercised by the contractor at subcontractor's or vendor's facilities). Quality cost data maintained by the contractor shall, upon request, be furnished the Government Representative for use by the Government in determining the effectiveness of the contractor's quality program.

In the Repair Division, this requirement only applies to production items whose contracts specifically require compliance with this section of MIL-Q-9858A. Because these items are dealt with infrequently, the Division has limited practical application of quality cost concepts.

3. Economics and Goals of a Quality Cost System

a. The Economics of Quality Costs

In the area of quality management, there exist two ways of approaching the concept of "economics of quality." One way is to believe that it is never economical to ignore quality. The other is to believe that it is uneconomical to

achieve 100 percent quality. [Ref. 33] Either of these approaches could create problems for management by allowing decisions on the level of quality to be made without specific standardized guidance. Consequently, managers working together with different approaches to the economics of quality will never reach the optimal level of quality. Therefore, the organizational goals of customer satisfaction and profit generation will be suboptimized. This is the reason organizations need to have formal quality management systems.

Most quality professionals accept Juran's original hypothesis on the optimum level of quality. Basically stated, the optimal level of quality is that level where the cost of prevention and appraisal are equal to the cost of failure (see Figure 3.1). However, this relationship has never been empirically verified in a scientifically rigorous manner due to a lack of empirical quality cost data [Ref. 34].

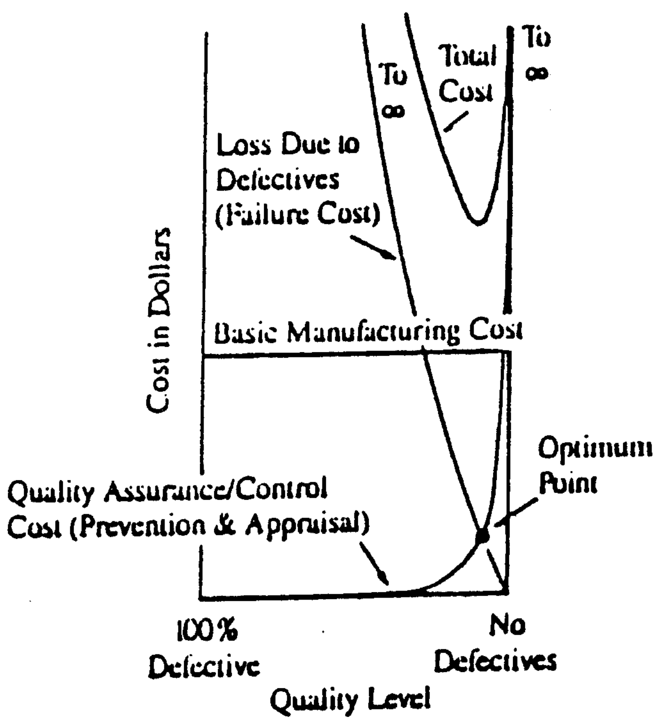

Figure 3.1. From Ref. [35].
Economics of Quality Costs, Traditional Processes

b. Goal of the Quality Cost Measurement System

The primary goal of a formal quality management system is to provide standard definitions, goals, and objectives of quality and the quality management system. As with any successful and comprehensive management system, the system for quality management must have the support of all levels of management, especially senior/top management. Concise reporting of established measures relevant to management objectives (for example, to provide high quality products and services at a reasonable cost and to operate in accordance with sound business practices) help to gain management attention and support. This is where the quality cost measurement system becomes relevant.

Properly established and used, quality cost measures are supposed to provide guidance to the quality management system just as cost accounting provides guidance to general management. Quality costs are a measure of those costs specifically associated with the *achievement or nonachievement of product or service quality requirements* [Ref. 36]. Therefore, the primary goal of the quality cost system should be to promote quality improvement efforts which lead to the reduction of operating costs.

Unfortunately, organizations without quality cost measurement systems, or ineffective systems, have the total costs of quality hidden among overhead and indirect costs. In his paper, "Quality Costs II, The Economics of Quality Improvement," John T. Hagan, ITT Corporation, estimated that less than 15 percent of the opportunities for quality cost application in manufacturing companies in the U.S. are actually being pursued in a profitable manner [Ref. 37]. This failure to track quality costs prevents management's analysis of the real impact of unconstrained increases in quality costs on the overall costs of operations. Research has revealed many cases where organizations have quality costs in excess of

20 percent of sales, yet identifying and managing these costs was not an objective of management. This finding implies that organizations which overlook the opportunity to control costs comprising more than 20 percent of their sales are not being effectively managed.

C. DEFINING AND CLASSIFYING QUALITY COSTS

1. Defining Quality Costs

Just as there is different terminology for these costs, so are there different meanings. Throughout this study the terminology "quality costs" is used to mean any cost resulting from efforts to assure a quality product or service, and any cost resulting from the failure to deliver a quality service or product to the internal or external customer.

2. Classifying Quality Costs

As discussed earlier, W. J. Masser was reportedly the first person to put quality costs into the four categories of prevention, appraisal, internal failure, and external failure. Although these four categories are generally used when determining the cost of quality for a particular organization, the definitions should be specifically designed to reflect the character of that organization's costs. Additionally, most quality professionals perceive the question of classification as less important than the proper identification and measurement of quality costs. Emphasis should be focused on using a classification scheme that is consistent throughout all quality cost reports subject to aggregation or comparison [Ref. 38].

When defining cost categories, it is best that the organization look at its operations and decide on definitions which are most suited for that particular organization. For

this study, definitions have been developed to clearly delineate the four cost categories for the Repair Division.

a. Prevention

These are costs stemming from the activities to assure the output of a quality product or service without the need for corrective action. This category includes activities such as quality planning, new item design, quality audits, quality training, and many others. Prevention, as defined here, focuses on the quality of the original output. Not included in this category are activities such as inspections and rework which prevent the defective product or service from being passed on to the external customer. In general, costs in this area are most important if prevention efforts are deemed insufficient.

b. Appraisal

Appraisal costs are those costs associated with determining if the original or subsequently reworked product or service is defective. Examples of appraisal costs are: tests of products, services, or processes; inspections of products and processes; inspections of incoming or purchased material; and final inspections of products. This category of costs also includes costs associated with the equipment, tools, and material used in appraisal activities. Appraisal is normally seen as a major area for improvement due to the inappropriate use of inspections in the quality process.

c. Internal Failure

Costs in the internal failure category are incurred because the original product or service was determined to be defective during an appraisal process. Internal failure connotes that the defects were found and corrective action taken before the product or service was passed to the

customer. Some examples of internal failure costs are: scrap, rework and repair, reinspect and retest. These costs normally represent an area where significant improvement opportunities exist.

d. External Failure

External failure costs are costs incurred because a product or service that was received by an external customer did not meet the customer's needs due to defects. The existence of external failure costs represent a general failure of the quality assurance/control program. The ideal level of external failure costs is zero. This is not realistic, however, due to the expense of sustaining administrative personnel, procedures, and materials just-in-case there are defects found by external customers. Still, costs in this area are a good source of improvement opportunities. Examples of external costs are: complaints administration, warranty administration, and repairs of defective items.

3. Establishing Bases for Quality Cost Measurement

Senior management, for whom quality cost reports will be prepared, will usually require something more than straight dollar figures to get the full impact of quality costs on operations. This is the purpose of measurement bases.

Measurement bases for quality cost are used to provide a clear picture of quality cost improvement trends over different periods of time. Quality cost experts feel that there should be various bases to represent the business from different perspectives. The British Standards Institution recommends that at least three measurement bases be used to relate operational activity to quality costs [Ref. 39].

The most important factor in determining which measurement bases to use is the relevance of the base to the

type of operational activity and objectives of the organization. All bases are not relevant to all organizations.

Other major factors to consider when using measurement bases are the methods for keeping them consistent. Bases must be adjusted to reflect changes in the levels of activity which affect them. Situations which may cause activity levels, and consequently, bases, to change are numerous. Some examples of these are: increased automation, changes in methods or processes of production, seasonal fluctuations, uncontrolled and unanticipated changes in material prices, or changes in production schedules.

It is recommended that, when possible, quality costs should be measured using the four normally available bases: the unit base, the labor base, the sales base, and the cost base. There is also one other base that is used, although less commonly than the other four, the value added base.

a. *Unit Base*

The unit base is used to relate quality costs to each unit of production. This measurement base is very simple and is easily understood by management personnel. The difficulty of using a unit base becomes apparent when the product mix, volume, or unit value is not constant.

b. *Labor Base*

This base is used to relate quality costs to either total or direct labor input, either labor hours or labor dollars, per unit of production. Using the labor base has the advantages of availability and understandability. However, investments in automation that displace labor, tend to have a profound effect on its significance.

c. Sales Base

Sales bases relate quality costs to each unit of sales. The sales base has mass appeal to the management of most organizations if the focus is on profit. Its appeal and relevance is limited in public organizations, such as military maintenance depots. This type of base is also subject to influence by changes in factors such as selling prices, marketing costs, and demand.

d. Cost Base

The purpose of a cost base is to relate quality costs to the costs of operations in a particular production segment such as a division or shop. This base has the advantage of offering more stability than the labor or sales bases because of the total scope of factors which make up the cost of operations. However, the cost base includes overhead costs which can hide quality cost factors and make it more difficult to target improvement opportunities.

e. Value-added Base

This base compares total quality costs to a measure of manufacturing activity unaffected by changes in sales. This type of base is useful when processing costs are important. They are not very useful in comparing departments, shops, or divisions that have completely different types of output.

4. Analyzing Quality Cost Trends

The function of a good quality cost measurement system is to provide information which aids management in determining where there may be opportunities for cost reduction. Simultaneously, this system should provide information regarding the performance of quality improvement efforts. The financial data provided by the quality cost system, when used

along with relevant bases provide management with the tools to analyze quality cost trends over various time periods. This dynamic analysis will allow management to determine if quality is improving.

Quality cost analysis is normally segregated into two categories of planning, long-range and short-range. Long-range or strategic planning focuses on accomplishment of major objectives and the overall mission of the organization over a long period of time such 2 to 5 years. Similarly, long-range quality cost analysis focuses on the long term progress of management plans. On the other hand, short-range quality cost analysis applies to the monitoring of the quality improvement efforts of the overall organization or individual segments of the organization during shorter periods of time, such as months or quarters.

The quality measurement system and the quality cost measurement system are interrelated. When actions are taken to improve quality, there will be a change in quality costs. Consequently, management personnel can evaluate the success or failure of specific corrective actions in the basic quality measurement system through the analysis of short-range quality cost data. Taking into consideration the lag-time between the cost data and the result of actions taken, management will be able to determine if an investment in period t_1 changes overall costs by period t_3. In a situation such as this, if acceptable results have been achieved, no other action may be needed. However, if by t_3 quality costs are not acceptable, different corrective actions may be necessary.

Many times corrective actions in the basic quality measurement system take the form of investing more in the early stages of production to reduce costs downstream. In his book on the cost of poor-quality, James Harrington [Ref. 40] uses data from a computer manufacturer to illustrate how investment in prevention and appraisal areas can provide huge

returns by reducing failure costs (Table 1). Harrington uses the following quote by then president of IBM, John F. Akers, to explain what is termed "quality-cost leverage":

> We have found significant financial leverage by investing in prevention and appraisal, both of which greatly reduce failure costs. Some of our divisions show extremely high payback on prevention investments, in both hardware and software. Fixing it in the lab before it reaches the field is where the payoff is. [Ref. 41]

Hardware		**Software**	
When corrected	Relative cost impact	When corrected	Relative cost impact
Component design	Negligible	Design/code	1X
Subassembly	1X	Internal test	20X
Unit	10X	After delivery	80X
Field	50X		

X = multiple factor

Table 1. Quality Cost Leverage. From Ref. [42].

D. USES OF QUALITY COSTS

1. Uses of Quality Cost Information

The manner in which any type of information is used depends on the person with the information. This holds true for quality cost information. Quality cost information can be used in many ways depending on organizational goals and objectives. According to Morse [Ref. 43], some of the most prevalent uses of quality cost information include:

- to stress the financial ramifications of quality,

- to point out the importance of quality problems,

- to serve as an aid in the evaluation of strategic capital investment proposals,

- to assist in establishing the goals or budget for quality efforts,

- to aid in the appropriate distribution of quality costs,

- or to evaluate the performance of quality improvement activities.

a. Financial Indicator

The most prominent way quality cost information is used is to bring management attention to the financial significance of costs related to quality. The most effective way this is done is by illustrating the relationship between quality costs and components of financial statements such as the income statement, balance sheet, net working capital statement, and the statement of manufacturing costs and variances. An example of this would be a balance sheet that carries an allowance for warranties. The specific amount of capital required to cover the costs associated with warranties is highly dependent on the reliability (an element of quality) of the organization's products. Therefore, the quality cost element, warranties, is specifically related to the balance sheet. [Ref. 44]

Once management clearly sees that quality costs are a major part of the cost of doing business [many times in excess of 20 percent of sales] hopefully, they will deem it prudent to control these costs.

b. Problem Indicator

Information gathered from the quality cost measurement system can be used to indicate the existence of quality problems. Analysis of these costs can allow quality officials to determine which quality problems provide the greatest opportunity for cost reduction or quality improvement. This, in turn, will help managers determine which areas should be addressed first.

c. Capital Expenditure Evaluation Tool

When used as a capital expenditure evaluation tool, quality cost information can aid in the diagnosis of cost savings anticipated as a result of strategic capital investment. Anticipated savings can be identified through analysis of the quality costs categories and specifying those which should decrease as a result of the investment project.

d. Quality Goals or Budget

The budget is one of the most valuable tools an organization has to plan and control costs, establish goals, and measure performance. Once an initial analysis of quality costs has been made and a quality cost measurement system has been put into effect, a budget can be developed that will allow achievement of specific quality goals.

e. Quality Cost Distribution

An obvious use of information supplied by the quality cost measurement system is the allocation of funds between the four cost catègories. Many times, analysis of quality cost information reveals that quality problems are the result of improper allocation of resources. High levels of failure costs such as warranty can often be decreased by

allocating more resources to prevention elements such as design.

f. *Quality Improvement Evaluation*

As previously discussed, costs related to quality can be used to determine if quality improvement efforts are successful. Through trend analysis, quality cost information can be used to evaluate whether improvement activities in one period reduced quality costs over future periods.

2. Limitations of Quality Cost Information

There are limitations associated with the use of quality cost information just as there are with any other accounting data or management report. These are discussed next.

a. *Problem Solving Ability*

Simply measuring quality costs will not solve the quality problems of an organization. Correcting problems associated with quality is the function of the management of the organization or subsection producing the defective output. To be an effective tool, the quality cost measurement system must be used in conjunction with a comprehensive quality improvement program.

b. *Corrective Action Indicator*

Reports on quality costs do not indicate specific corrective actions required to make quality levels acceptable. Selection of corrective actions for quality problems is the job of quality professionals and managers. Quality cost reports and quality improvement techniques are tools required to get the job done properly.

c. *Mismanagement*

Quality costs can be mismanaged in attempts give the appearance that improvement efforts have reduced costs in the short-term. Normally, quality cost reduction should be a long -term goal. Quality and productivity improvements are more appropriate as short-term goals. Investments in effective quality management programs will increase productivity in the short-term and will eventually payoff by reducing overall quality costs.

d. *Results Coordination*

Due to the time lapse between quality improvement efforts and their eventual results, it is often difficult to match specific efforts with direct accomplishments. To overcome this difficulty, management must plan for specific outcomes when planning specific actions.

e. *Cost Omissions*

Omitting necessary quality costs from reports allow them to remain uncontrolled. Although the initial quality cost measurement system will possibly omit several important costs, continuous improvement of the system should correct this limitation.

f. *Cost Inclusions*

Inclusion of unnecessary costs in quality cost reports is not as important as omitting necessary costs as long as they are financially immaterial. This limitation is similar to the previous category in that the continuous improvement of the quality cost measurement system should eliminate the inclusion of unnecessary costs.

g. Incorrect Measurement

Incorrect measurement of quality costs is an unavoidable limitation due to the categorization of overhead costs. Allocating overhead costs, like supervisors' salaries, to each quality cost category is a subjective matter that cannot be made with absolute accuracy.

E. QUALITY COSTS SYSTEM IMPLEMENTATION

Literature on how to establish a quality cost measurement system is plentiful. The methodologies outlined throughout much of this literature vary slightly, yet the essence of these methodologies is the same; getting the initial program up and running. Robert M. G. Millar, Director of Quality Management, ITT, made the following statement concerning the establishment of a quality cost measurement system:

> Grab someone else's idea and get started...then debug it and continually improve it. Don't sit around trying to develop a fantastically comprehensive system. [Ref. 45]

A good quality cost system is one that is tailored to the needs and objectives of the particular organization using it. This section will outline one method which can be used by the Repair Division to develop a system to fit their quality costs needs. The following twelve step method is offered by Wayne Morse and his coauthors in their book on quality costs [Ref. 46].

1. Management Commitment and Support

The establishment of a successful quality cost measurement system will definitely require the full commitment and support of top management. In some cases top management will take the lead and direct the implementation of the system. However, frequently the idea of installing a quality

cost system originates from either the quality control or accounting department. In the latter case, there has to be a plan to convince top management that this type of reporting system would be a benefit to the organization. In doing this, an initial study of quality and accounting data must be made to verify the assumption that the proposed system would benefit the organization. Normally, this initial study will only identify total costs related to quality. It will not attempt to properly separate the costs into the four quality cost categories. Most literature on quality costs recommend focusing on areas which will illustrate high failure costs because of the potential for greater improvement.

The ideal situation when gathering data for the initial cost study is to form a cross-functional team with representation from all areas involved. Additionally, using information from the current quality control and cost accounting reporting systems would be ideal. If, however, it is not possible to form a cross-functional team, the impetus to gather the necessary information will normally fall on the department initiating the proposal. Also, if the current cost accounting system does not provide all the needed information, logically derived estimates should be used and supported.

After gathering all the data needed to support the benefits of the quality cost system, a presentation must be made to management. If the information used was not gathered by a cross-functional team, to support its validity, the information should be reviewed by competent personnel from the departments supplying the information.

In deciding who should make the presentation, consideration must be given to the authority, reputation, and credibility of the presenter. Also, the audience (level of management) must be taken into consideration when preparing and presenting the data to ensure the appropriate level of detail is addressed in the presentation.

2. Installation Team

If the decision to install a quality cost system originated with top management or top management support and commitment has been gained through the presentation of convincing data, a plan must be developed for installing the system. If a cross-functional team was not formed to gather the data for the initial study, it is imperative that one be formed to install the system. This team should be composed of individuals from every area of the organization. This is necessary because all areas are involved in creating quality costs, therefore, each area should take part in identifying those costs to be captured by the system.

The purpose of the installation team is to develop a comprehensive plan for installing the system. This involves educating team members, management, and other individuals who can assist in creating a critical mass of personnel knowledgeable of quality cost concepts. Other responsibilities of the installation team are to: develop a series of steps for system implementation, determine the objectives of the system and actions to meet these objectives, provide guidance as the plan is carried out, and evaluate and recommend improvements for the system.

3. Prototype Selection

The initial installation of any new system in an organization can cause major disruptions in normal operations. One method of reducing the disruptive impact of installing a quality cost measurement system is to use one segment of the organization as a prototype. Once the system is operating successfully, it can then be expanded as management deems appropriate.

In selecting the business segment to start the program, some major questions which should be considered are:

- Is the area self-contained?

- Is there a formal, working, cost accounting system?

- Can the area derive long-term benefits from quality improvement?

- Is the management open to change?

The answers to these question will allow the team to determine such matters as:

- whether the costs in the area can be evaluated against specific measurement bases,

- the level of detail captured by the current cost system,

- the level of support required from other departments and upper management over the trial period,

- and how the managers of the area will accept recommendations to change the way they do business.

4. Users and Information Suppliers' Support

Maintaining the support and cooperation of the users of the information provided by the quality cost reporting system, and that of the information providers, is critical to the success of the program. Ensuring that the installation team has members representing the information users and information providers is one way of facilitating the needed support and cooperation. These team members will act as facilitators by keeping the communications open to the segments they represent.

5. Quality Costs and Quality Cost Category Definitions

To ensure a clear understanding of what costs are considered quality costs, and where these costs will fall in each of the quality cost categories, definitions are needed. The definition for quality costs must be easily understandable by everyone involved. Additionally, the quality cost

categories can be the usual four, or they can be unique to the organization. The overall objective in defining quality costs and quality cost categories is to make them a part of the normal operations of the organization.

6. Quality Costs Identification

Using the definitions developed by the team, the next step is to identify the types of costs included in each category. This will involve researching the cost accounting system codes, and seeking the advice of knowledgeable individuals in different areas where costs are generated. Once the cost types have been determined and categorized, coding is recommended to make them easy to distinguish and sort by category. Coding is especially necessary if the system is to be computerized.

7. Quality Cost Information Source Determination

There are two primary sources of quality cost information, the current cost accounting system and the areas generating the costs. In most cases, the current cost accounting system will provide the preponderance of the quality costs. Additionally, other cost elements can be retrieved from the current cost system with some modification. An example of this would be the allocation of an overhead cost, such as a supervisor's salary, to the different quality costs categories of prevention, appraisal, and failure categories.

Inevitably, there will be cost elements that are not found in the current cost accounting system, and cannot be extracted from the current system. If the program installation team determines that these costs are material, estimates will be necessary.

Estimates of labor related quality costs can be made simply by using time cards annotated with the cost element

codes. Material related costs can be more difficult to determine since the work must first be performed, inspected, rejected and disposed of before it is categorized as scrap. In some organizations there are standardized procedures for determining scrap costs, but others do not have standards.

Due to the significance of scrap costs in most manufacturing organizations, methodology should already exist for determining and recording these costs. If an organization considering the implementation of a quality cost system does not, the installation team should work to develop procedures for identifying and collecting these costs.

8. Quality Cost Reports and Graphs Design

The next step to be taken by the installation team is to develop the formats of the reports and graphs to be used to summarize the quality cost information. The principal consideration here is designing presentation vehicles which convey the appropriate information for the level of management receiving them. The presentation vehicles should begin with a high degree of detail at the lower levels of management and become less detailed as the level of management gets higher.

The use of standardized measurement bases (discussed earlier) is recommended to adequately adjust for activity levels. These measurement bases also help to maintain a constant perspective over time.

9. Quality Cost Information Accumulation

The methods for collecting quality costs must be specified by the installation team. Individuals responsible for collecting specific costs must be identified and educated on how and where to collect the costs. The forms for collecting and reporting the costs must be designed and disseminated to the individuals generating quality costs.

Additionally, computerization of a collection and reporting system may require data systems specialists.

10. Report Preparation and Distribution

The preceding steps should have made available all the information needed to carry out this step. The only detail left is to institute procedures for putting together the reports and ensuring they are disseminated to the right people. It is recommended that, initially, the reader be made aware that the report is new. Also, a brief analysis of the information contained in the report should be included, along with specific points of interest, and suggested conclusions to be drawn from the data.

11. Error Correction

Once the system is in place and the initial reports made, there may be a need to revise components of the system. These changes may be required to improve the reliability of the system, to make the collection forms easier to use, add new costs, remove unnecessary costs, and many other factors which might make the overall system more effective.

12. System Expansion

When the installation team is convinced that the quality cost measurement system is working well and providing benefits to the prototype organization, it should make a recommendation to top management to expand the system to other segments of the organization. If management agrees, plans should be made to start the expansion. These plans should include bringing in new members to the installation team to make use of new perspectives, and to increase the number of personnel with indepth experience of quality cost systems. The periodic audit and evaluation of the system should also be included in

the expansion plans. This will ensure the continued effectiveness and efficiency of the system.

F. QUALITY COST REDUCTION

As previously stated, the purpose of the quality cost measurement system is to provide management with a tool to assist them in finding opportunities for quality improvement. It has also been insinuated that improvements in quality reduces costs. An underlying thought is that the quality cost measurement system itself does not and can not reduce costs. An essential element of cost reduction is the existence of a formal quality improvement program.

Some questions management will normally ask when presented with reports generated by the quality cost measurement system are:

- What are our quality costs supposed to be?
- How do our quality costs compare with organizations similar to ours?
- How can we reduce our quality costs?

Unfortunately, there are no set answers for these questions. In addressing the first question it is safe to say that there is no way to determine what an organization's quality costs are supposed to be, other than to say they probably should be lower than they are currently. Figure 3.1 illustrated the tradition model of quality costs where total quality costs rise indefinitely as quality approaches perfection. The new model of quality costs (Figure 3.2) illustrates the ability to achieve perfect quality at finite costs.

This model takes in to account the technological advancements in manufacturing which help maintain low error

rates without creating additional costs. Therefore, the management of an organization must determine the level where quality costs are acceptable to them.

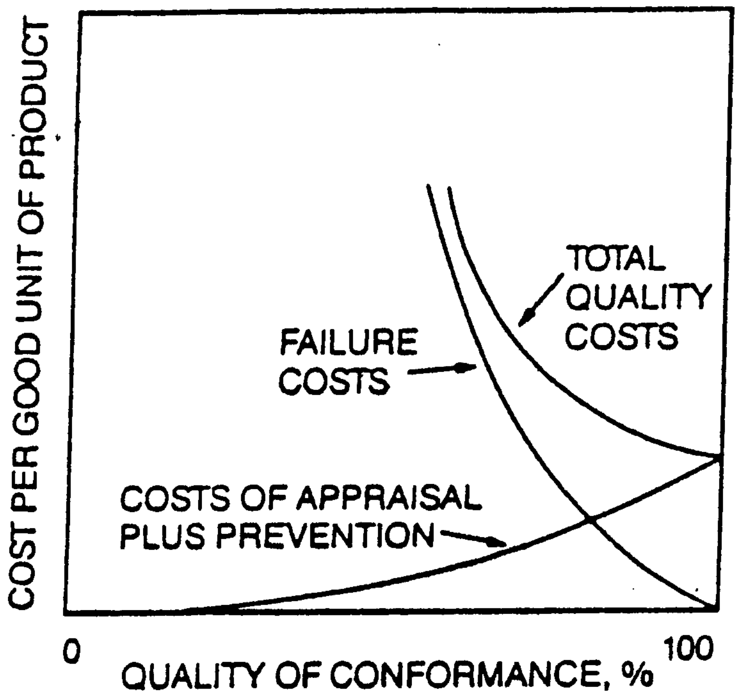

Figure 3.2. From Ref. [47].
Cost of Conformance, %, Emerging Processes

One answer to the second question of comparability of quality costs between different organizations is that quality costs are specific to each organization. Measurement of these costs vary from one organization to another. Therefore, unless the organizations are operated identically, and the measurement systems are identical, they cannot be compared.

The last question, "how can we reduce our quality costs," is best addressed by the quality assurance and quality improvement personnel. It is the responsibility of these professionals to continuously look for ways to improve the quality of the outputs of internal and external producers. Using the tools and techniques for continuous process

improvement, they should be able to find and correct the problems identified with the aid of the quality cost measurement system.

G. CONCLUSION

This chapter has presented information to give the reader an understanding of quality cost concepts, uses and limitations, and the methodology for implementing a quality cost measurement system.

The guidance provided in the twelve steps presented above was considered during construction of the conceptual model of quality costs for the Repair Division, which will be presented later.

Chapter IV will present the methodology followed in conducting the research for this study.

IV. METHODOLOGY

A. CHAPTER INTRODUCTION

This chapter provides a more detailed discussion of the techniques used for gathering the research data, selecting the organizational entity, and formulating the design and structure of the study.

B. RESEARCH METHODS

The primary method of research for this COQ study was through the use of archival cost, production, and budget data pertaining to MCLB Repair Division's Fiscal Year 1993 (October 1, 1992 through September 30, 1993). This data consisted of various document sources open to the public and some "business sensitive" document sources. Personal interviews using unstructured questions were also used to gather information.

The information gained through personal interviews was of primary importance in developing a feel for the way in which the division operated. It also assisted the researcher in dissecting the archival data and retrieving data essential to this study. Following is a brief discussion of the data provided by the most pertinent information sources.

1. Quality Progress Report

This report is compiled by the Statistical Services Unit, Quality Evaluation Section, Quality Control Branch of the Repair Division. It is a bi-monthly report which provides statistical data for the analysis of quality improvement. The primary information provided by this report focuses on the total number of inspections performed by the QC inspectors and the defects uncovered, segregated by Cost Work Center (production shop), as a result of the inspections performed.

Due to the Quality Control Section's reliance on defect discovery as a measure of quality, the research determined a need to use the information concerning defects in analyzing the relationship between quality costs and the number of defects reported.

2. Marine Corps Depot Maintenance Biennial Budget Submission (FY 94-95)

The budget submission is compiled and monitored by the Financial Management (FM) Section of the Repair Division. This document is a source of information normally found on corporate financial statements such as the balance sheet, income statement, and statement of cash flows. The contents include information such as: balance sheet, financial condition, and revenue and expense statements, personnel data, price and program changes, G&A expenses, and many other financial data items. It also contains the total operational expenses for the Division for fiscal years 1991 through 1995 by line item. The actual expenses for fiscal years 1991 through 1993 are shown, as well as budgeted expenses for fiscal years 1994 and 1995.

The Depot budget submission is a "business sensitive" document, meaning that although it is not officially classified, access to it is considered limited. Personnel from outside of the MCLB should have the permission of the director of the division or his superiors to see the budget. The researcher was granted authorization to obtain a copy of this document by the head of the FM Section, in conjunction with guidance from the Maintenance Directorate.

3. Repair Division Cost Work Center (CWC)/Control Center (CC) Summary

A product of the FM Section, this document is the complete listing of standard General and Administrative (G&A), Production Expense (PE), and special use account codes

utilized by the Repair Division. It also lists all the cost categories used for constructing the Job Order Numbers (JONs) used to capture cost in the financial accounting system. Updated annually, the account codes used in conjunction with the JONs are the sole means of accumulating costs using the current accounting system. Therefore, the information contained in the summary was the primary means of determining the cost data to be included in the model.

4. Depot Maintenance Activity FY93 Total Operating Expenses Plan

The Expense Plan is another product of the FM Section considered to be "business sensitive." This document is an itemized list of all the planned operating expenses for the division, subdivided by CWC. These expenses are used by the FM Section to calculate the direct and indirect regular labor rates, G&A expense rate, direct and indirect overtime labor rates, and total labor rates (with overhead already added) to be utilized by personnel in all production areas where costs are applied to specific jobs.

5. The Depot Maintenance Management System (DMMS)

The DMMS is the current cost accounting system used by the DMA. This system has been in place since the 1960's and was seen as a computer-based system set up to support manual operations and help keep overhead low. [Ref. 48] The way this system was to hold down overhead costs was by limiting the level of detailed information handled by the system; thereby, limiting the amount of time spent manually inputing data.

The system is subdivided into labor and material subsystems. The labor subsystem is primarily directed toward accumulating costs for determining payroll and applying labor charges to production jobs. The material subsystem is used to keep track of inventory used, on order, and on hand. The

costs associated with the material used or ordered for a particular production item are applied to that job as they occur.

The DMMS can accumulate and report total costs for each element of the CWC/CC Summary. Therefore. the system was used to provide the specific dollar amounts associated with the cost categories selected from the CWC/CC Summary. This data is the basis for the costs included in the model.

6. DOD Depot Maintenance Operations Indicators Report

This report presents performance data for all DMAs in the DOD. It was compiled by direction of the Joint Policy Coordinating Group on Depot Maintenance (JPCG-DM). The purpose of the report was to provide measurement data by which the performance of the various depots could be compared. Although the report was discontinued at the end of FY93 because of nonstandardized methods of accumulating costs throughout the DMAs [Ref. 49], it did provide valuable data from which measurement bases could be calculated for this study.

C. MODEL DEVELOPMENT

In determining how to design the conceptual model for quality costs, numerous formats cited in various literary sources were examined before determining the specific model form. Because quality costs are specific, in definition and categorization, to each individual organization, there is no standard format for accounting for them. Therefore, it was necessary to develop a COQ model for the Repair Division instead of selecting one developed for use by some other organization. The format of model presented as Appendix A is the researcher's derivative of those cost elements that should be included in an initial COQ report format for the DMA.

D. ORGANIZATION SELECTION

The organization or organizational segment selected for study had to meet several criteria. It had to be self-contained, produce a measurable output, have its own management system, and have a system in operation which would collect the cost associated with its operations. The Repair Division of the MCLB, Albany was chosen as the target of the study because it is an autonomous division of the Marine Corps Logistics Base, with its own mission, quality programs, budget, and cost system. This division plays a vital role in the accomplishment of the overall mission of the Marine Corps Logistics Base by performing repair and maintenance on combat essential equipment to a degree unobtainable by lower level repair facilities.

E. DATA COLLECTION

An on-site visit to Repair Division, MCLB, Albany was conducted to initiate data collection. The following areas were examined to assess the current use of quality cost concepts: the quality control/assurance program, the TQL program, the mission, and the cost system.

As part of this visit, personnel relevant to the functions of directorate management, quality control/assurance, TQL, production control and scheduling, customer service, engineering, and financial management were interviewed using unstructured interview questions. During these interviews, initial data was collected or requested to begin the analysis. As additional data not collected during the on-site visit was required, those original personnel were contacted to render assistance in gathering data from supplementary sources. They also were of valuable assistance interpreting the information contained in the primary sources previously discussed.

F. MISCELLANEOUS PROCEDURES

The cost data gathered from the various sources discussed were analyzed as to which of the four COQ categories it should be placed. Of course there were cost elements which had to be allocated to more than one category. In these instances, judgement was used to apportion costs by quality cost category. Veritably, the categorization of all the costs shown on the model are the result of the researcher's judgement, just as they would be left to the judgement of the organization's COQ study/installation team.

There were cost elements which were significantly represented in the literature on COQ, such as scrap and rework, which were not specifically identified by the current cost accounting system. Because an organization such as the Repair Division cannot operate without producing some level of scrap and rework the judgment was made that they were hidden in other areas. Given the time constraints of this study and its focus on historical data, a means of estimating the cost of rework and scrap could not be developed. However, every effort was made to include those cost elements which may contain other hidden costs. An example of these elements would be Field Service and Travel. This area would include costs associated with funding rework teams to correct equipment defects not found before shipping the equipment to the customer. Another example would be Sale of Scrap. Although this element does not specifically state the full cost associated with producing an item which is eventually coded as scrap, it does indicate that scrap is being produced and that it does have a specific value.

G. CONCLUSION

This chapter described the basic methodology used to select, accumulate, interpret, and format the data used to comprise the COQ model presented as Appendix A.

The next chapter, Chapter V, will present the analysis of the data contained in the model.

V. ANALYSIS

A. CHAPTER INTRODUCTION

This chapter presents data derived from the analysis of the COQ model and from the information collected while searching for the answers to the primary and secondary questions that were the focus of the study. This chapter is not meant to provide explicit answers to the research questions, yet the answers should be easily deduced from the data provided. Details on the cost data collected for Fiscal Year 1993 are provided in Appendix A to this thesis. Note that some of the cost data was not available for various line elements in each of the four categories of COQ. The impact of this missing data is that the total COQ is assumed to be understated.

Additionally, it is assumed that the missing costs are not included in other elements covered by this study and that they remain hidden in detailed production and accounting records not available to the researcher.

B. RESULTS REGARDING THE PRIMARY RESEARCH QUESTION

The primary research question which this study attempted to answer was, "Can the management of the Repair Division... benefit from a program directed toward the identification of costs related to the pursuit of quality?" This section includes the analysis of some of the most pertinent quality cost data which resulted from the research efforts directed toward answering this question.

1. Total Quality Costs

To make it easier for the reader to follow the analysis of total costs, Table 2 provides a summary of applicable data extracted from Appendix A.

The study revealed that the total COQ for the Repair Division was approximately $7.077 million. This amount is accurate only for the data collected and would be different if costs for all of the COQ elements in Appendix A had been available.

Of the total COQ, approximately $4.177 million was made up of prevention and appraisal costs (commonly referred to as conformance costs). This equates to approximately 59% of the total amount. The remaining $2.9 million made up the failure costs (commonly referred to as nonconformance costs).

COQ SUMMARY

FY93 ($000)

CATEGORY	**1st QTR**	**2nd QTR**	**3rd QTR**	**4th QTR**	**Total**
Cost of Conformance					
Prevention	370	378	368	295	1,411
Appraisal	725	741	722	578	2,766
Totals	$1,095	$1,119	$1,090	$873	$4,177
Cost of NonConformance					
Internal Failure	680	696	677	542	2,595
External Failure	80	81	80	64	305
Totals	$760	$777	$757	$606	$2900
TOTALS	**$1,855**	**$1,896**	**$1,847**	**$1,479**	**$7,077**

Cost of Conformance as % of total - 59%
Cost of Nonconformance as % of total - 41%

Table 2. Total COQ Summary.

In the nonconformance categories of internal and external failure, the elements comprising the majority of these costs are: price variances, Report of Discrepancy (ROD) credit denials, accidents and injuries, and reinspection/retest costs (see Table 3). These four elements comprised over $1.7

million, or approximately 60% of the $2.9 million attributable to nonconformance costs. The four nonconformance elements, therefore, represent approximately 24% of the total $7.077 million of COQ (see Table 3).

The significant amount of expenditure in the few COQ elements should be an indicator to management that there are sufficient opportunities for cost reduction to warrant the need to know their COQ and install a COQ measurement system.

Major Elements of Nonconformance Costs

Total Nonconformance Costs		2,900,051
Major Internal Failure Costs		
Price Variances		449,487
RODS/Credit Denied		197,177
Accidents & Injuries		906,856
		1,553,520
Major External Failure Costs		
Reinspection/Retest		179,035
Subtotal	(59.74%)	1,732,555

1,732,555 (Major Nonconformance costs) ÷ 7,077,481 (Total COQ) = 24.48%

Table 3. Nonconformance As Percentage of Total COQ.

2. Quality Cost as a Percentage of Unit Cost

In examining the cost elements included in the COQ model, it is apparent that there are a number of areas for which costs could not be collected (see Appendix A). Even with the missing or hidden elements of cost, (e.g., returned product costs, return costs, set-up of inspection and test, scrap, and rework) quality costs were on average **8.1 percent** of the cost of each unit produced by the division. This percentage also applies to total quality costs as a portion of direct labor

cost. This is the result of the methodology used by the DMA to calculate the total cost of direct labor for reporting purposes. The method used in the Depot Maintenance Operations Indicators Report (1st Quarter FY92 thorough 4th Quarter FY93) simply divides the accumulated total cost of production by the total number of direct labor hours applied in production. This makes the total cost of direct labor equal to the cost of the total number of units produced.

The assumption is made that the percentage of quality cost per unit would have been substantially higher if all costs had been available. This assumption takes into consideration the type of combat equipment sent to the DMA, the specialized work performed on each unit, and elements such as return cost [which are not included in the cost of operations of the DMA].

3. Test and Inspection Cost Per Unit

Another cost element which is highly relevant to answering the primary research question is cost of test and inspection for each unit produced by the division. The total operating costs for FY93 were $86,900,941. The average total cost of each unit produced (calculated using the total operating costs divided by 54,886 units produced) is $1,583. Of this amount, $13.74 is the cost of tests and inspections as calculated from those costs available at the time of the research.

The total number of inspections performed during FY93 was 128,243. This number does not include all the testing required by the division's mission statement such as: receiving inspections, preinduction inspections, and nondestructive testing inspections. Given this number of inspections, it is assumed that the calculated amount of $13.74 would have been higher if fully detailed cost data for tests and inspections had been available to the researcher.

4. Quality Cost as a Percentage of Revenue

The DMA is considered a revenue producing organization under the Defense Business Operating Fund (DBOF). Under the DBOF concept, the revenues generated by the DMA should be approximately equal to the cost of operations. An examination of the information provided by the COQ model indicates that the total cost of operations for the period covered by the study were greater than the revenues generated. An explanation for this unfavorable financial position was provided in the *Depot Maintenance Operations Indicators Report, 1st Quarter FY92 Through 4th Quarter FY93*. This document contained the following statement:

> In both FY92 and FY93, there was a planned loss of accumulated operating results directed by the Defense Business Operating Fund (DBOF). This loss was achieved through a negative surcharge applied against our total stable labor rate, therefore, reducing our revenue. In addition, workload increased significantly to meet priority... requirements...

To provide further explanation for the imbalance between revenues and operating costs, the total cost of quality as a proportion of revenue was calculated. On average, quality costs were approximately **10.5 percent** of the total revenue for FY93. While the percentage of quality costs to revenue calculated from the data in the model did not exceed 20 percent (Chapter III, section B.3.b.), it is significant. Considering the fact that fully detailed production and cost reports were not available for analysis by the researcher, the assumption is made that quality costs as a percentage of revenue is understated in this study.

Individually, the quality cost categories ranged, on average, from a low of .04 percent of revenue for external failure, to a high of .41 percent of revenue for appraisal.

Even without considering the data not included in the model, the costs associated with quality were a very significant percentage of overall operating costs. Additionally, since total revenue was understated, quality costs were also a significant percentage of revenue.

5. Relationship of Defect Rates to Quality Costs

The DMA management considers the number of major and minor defects detected through inspection to be a measure of performance in their efforts to achieve quality. As a primary measure of quality and an indicator of process improvement, the number of defects could correlate to quality costs. Table 4 presents this relationship.

Defect Rates to Quality Costs

	FY93				
Quarters	**1st**	**2nd**	**3rd**	**4th**	**Total**
Defects, Major	480	1056	557	572	2665
Defects,Minor	319	754	4938	4707	10718
Total	799	1810	5495	5279	13383
Inspections	26528	40038	27476	34201	128243
Units Produced	10336	16381	12282	15887	54886
Total QOC ($000)	1854	1897	1847	1479	7077
Inspections/Unit	2.57	2.44	2.24	2.15	2.34

Table 4. Relationship of Defect Rates to Quality Costs.

Taken at face value, the data in Table 4 could indicate a slight correlation between quality costs and defects detected. In this case, the first two quarters with higher quality costs have fewer overall defects than the last two quarters with lower quality costs. However, another way of looking at the relationship between quality costs, inspections, and defects is that the first two quarters have

higher quality costs due to a higher ratio of inspections to units produced (2.57 and 2.44, respectively) than the last two quarters (2.24 and 2.15). In this case, the data contained in the model does more than indicate a correlation between the level of spending associated with quality and the rate of defects detected. It more specifically points to a relationship between higher rates of inspection and higher quality costs. Additionally, the model indicates that a higher number of defects does not automatically result from more inspections. The second quarter with the largest number of inspections had fewer defects detected than the third and fourth quarters with fewer total inspections. However, the second quarter did have the largest number of major defects as a result of the higher number of inspections.

6. Supplier Related Quality Costs

The total amount of supplier related quality costs included in the model was $662,581. This amount is calculated as follows:

(Shipment shortages + RODs/Credit Denied + Loss Shipments + Price Variances) = Total Supplier Related Costs

($5,796 + 197,177 + 10,121 + 449,487) = $662,581

Calculated as shown above, supplier related quality costs account for approximately 26 percent of the total internal failure costs. In view of this high percentage of costs being concentrated in one area, these costs present ample opportunity for improvement in the area of supplier quality.

C. RESULTS REGARDING THE SECONDARY RESEARCH QUESTIONS

Two of the secondary research questions concerned the mission of the Repair Division and the TQL initiatives used in the division. The specific questions were: "What are the

mission objectives of the Repair Division?" and "What TQL initiatives for improving quality are currently in use or have been proposed for use by the DMA?" Chapter II provided, in detail, the mission objectives of the division. It also fully outlined the TQL program currently in use. Therefore, further discussion of these areas is not deemed necessary. The findings related to the remaining secondary research questions are presented in the following subsections.

1. Cost System Adequacy

The question, "Is the current cost system at the DMA adequate to properly identify and aggregate the costs associated with quality?" was asked as a consideration for secondary research. In Chapter IV a brief discussion was provided on the various information sources used to derive the data contained in the model. There was one section which introduced the DMMS as the cost accounting system used by the DMA.

The DMMS is a very old system which has been continued because it supports manual operations and meets the requirements of applicable directives. In meeting these objectives, it has the attribute of achieving limited detail in its accumulation of costs. To gather the cost data for the detailed COQ elements contained in the model, other data sources had to be queried and analyzed (see Chapter IV). After analyzing the data to determine the proper costs to be associated with quality, further analysis was required to determine the quality cost categories to allocate them to and the proportions to allocate to the different categories. The aggregation of this data was performed manually utilizing spreadsheets and personal judgement due to the inherent weaknesses of the DMMS.

As mentioned earlier, examination of the model in Appendix A reveals several cost elements which do not have

costs allocated to them. The absence of these costs is also directly attributable to a weakness of the DMMS. Because the DMMS only collects costs at a specified level of detail, there are no other systems in place which require greater detail in accounting for costs.

2. COQ Model Development

In Chapter III, the implementation of quality cost systems and initial quality cost studies were addressed. The point was made that a good quality cost system is one which is tailored to the needs and objectives of the organization using it. Further, it was pointed out that the installation team has the responsibility of determining what costs to include and how to develop those costs. These findings relate specifically to the secondary research question: "Is the model provided the only way to develop a COQ model for the DMA?"

During the analysis of the information provided by the various data sources, the design of the model became apparent. The model presented specifically attempts to maintain a high degree of integrity between the current cost accounting system and the cost elements that would be considered appropriate given the operations of the DMA. At the same time it is designed to provide indications of the level of detail needed in a cost accounting system specifically designed to support a quality cost measurement system.

D. ADDITIONAL RELEVANT FINDINGS

An additional finding was that there had been several attempts and studies made to develop and replace the DMMS with a more technologically advanced, user-friendly cost accounting system, able to achieve greater detail in cost accumulation. The latest official attempt to replace the DMMS resulted in a study commissioned in February 1991 by the Marine Corps Deputy

Chief of Staff for Installations and Logistics (DCS(I&L)). The final conclusion to this $400,000, eight month study was that the Marine Corps should replace the DMMS with a commercial, off-the-shelf system. However, due to the desire of DOD to select an existing system as the standard for all maintenance depots, there has been no action to change or modify the DMMS. At the time of this study, efforts by the Joint Logistics Systems Command (JLSC) to find and implement an acceptable system to replace the aged DMMS were ongoing. [Ref. 50]

Another relevant finding was a *Depot Maintenance Performance Indicator Study*. This study was performed by a joint-Service study group headed by Lynn Greer and Jim Kennedy, from the Office of the Assistant Secretary of Defense, Production and Logistics (OASD(P&L)). At the request of the Assistant Deputy Under Secretary of Defense (ADUSD) for Maintenance Policy, this study group was to assist the DOD maintenance community in developing depot maintenance performance indicators and associated reporting system that would satisfy the needs of local management and Congress. [Ref. 51]

In this Defense Analysis and Studies Office (DASO) report, dated December 1993, extensive research was conducted throughout 29 DOD organic depot maintenance activities and privately run businesses to determine the major factors enhancing an organization's ability to change in a competitive environment and to focus and motivate the work force. The results of this study prompted a number of recommendations focusing on five areas to improve performance information. These five areas were: quality, customer satisfaction, inventory, financial and accounting, and overhead. Below is an abbreviated list of the recommendations made by the study group [Ref. 52].

- track scrap and rework
- track appraisal and prevention costs
- track number of supplier defects or rejections
- measurement of each expense item as a percent of sales
- track materiel availability
- track supplier timeliness and quality

Several of the areas where the DASO study recommended improvement are the same areas in which there were either relatively significant quality costs (e.g., supplier related costs) or no quality costs (e.g., scrap and rework) contained in the model. Throughout this chapter it was noted more than once that the current accounting system is not capable of accumulating costs in sufficient detail to support the measurement of quality related costs. The recommendations of the DASO study indicate that the deficiencies found in the cost accumulation and reporting systems of the MCLB Albany DMA are not unique to them, but are areas for improvement throughout the DOD.

E. CONCLUSION

This chapter presented the analysis of the data collected during the research. It specifically related the data to the primary and secondary research questions posed as the basis for the research efforts. The specific answers to the research questions concluded from the analysis of the data will be presented in Chapter VI.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. INTRODUCTION

The Repair Division has implemented a very comprehensive TQL program to create an organization which better serves its internal and external customers. The TQL program and its relationship with the quality assurance function of the organization has a myriad of costs associated with it. The focus of this thesis has been on COQ as an element of the division's TQL/continuous process improvement plan. Thus far, the COQ element has not been emphasized in the effort to improve the quality of the organization and its products. Chapter V and Appendix A attempt to make the point that in order to truly become a "total quality" organization, the DMA has to view COQ as a necessary tool for proper management of their TQL program.

B. SPECIFIC ANSWERS TO THE RESEARCH QUESTIONS

The answer to the primary research question of, "Can the management of the Repair Division, MCLB, Albany benefit from a program directed toward the identification of costs related to the pursuit of quality?" is yes. Given the information in Chapter V regarding this question, there appears to be an abundance of opportunities for the improvement of quality processes and quality cost management.

The first two secondary research questions, "What are the mission objectives of the Repair Division?" and "What TQL initiatives for improving quality are currently in use or have been proposed for use by the DMA?" were answered in Chapter II. As an addendum to the information provided in Chapter II, this researcher views the Repair Division as currently highly successful in fulfilling their assigned mission. The division's ability to reorganize workload schedules and remain

responsive to needs of the operating forces is critical to the success of the Fleet Marine Forces.

Another secondary research question that was asked was, "Is the current cost system at the DMA adequate to properly identify and aggregate the costs associated with quality?" The data collection and analysis processes outlined in Chapters IV and V indicate that it is not.

Some of the areas where improvement is warranted in the cost collection and accounting system are the collection of costs related to the following:

- scrap and rework
- supplier quality
- quality planning by other functions (e.g., Engineering)
- training test and inspection personnel
- receiving, preinduction, and NDT inspections
- calibration and metrology support
- set-up of inspection and test equipment
- personnel qualifications
- reviewing test and inspection data
- field testing and inspection
- rework of supplier rejects
- absenteeism
- remedial engineering
- loss of billing discounts
- troubleshooting
- substandard product costs
- extra production operations
- returned product costs

- recall costs

- return costs

The fourth question considered for secondary research was, "Is the model provided the only way to develop a cost of quality model for the DMA?" To answer this question this researcher submits the model in Appendix A. This model is the result of one individual's research and judgement. In Chapter III there were twelve steps provided as guidance in establishing a COQ system.

C. CONCLUSIONS REGARDING THE RESEARCH QUESTIONS

The following conclusion can be drawn from the answer to the primary research question: The proportion of revenue and unit cost accounted for by quality costs indicate that quality costs should be an area of management attention. Using the data available to formulate the model, calculations indicate that management of the DMA was spending approximately ten and a half percent of their revenue without the ability to specifically account for it. Additionally, there were no indications that specific plans had been made for its expenditure. Even this amount is considered understated due to the previously mentioned areas where cost data was not available.

Additionally, the enormous number of inspections conducted to yield such a small number of detected defects, and the realization that the costs in the appraisal category comprise the greatest portion of quality costs given the inability to measure scrap and rework costs. Both these areas warrant a more indepth evaluation of the use of inspections in the quality assurance process.

Since 1992 the Repair Division has been investing enormous amounts of effort and money into the implementation

and propagation of their quality improvement program. Management should now have some idea as to whether or not results are being obtained which are commensurate with the effort and money being invested. To these ends, the conclusion can be reached that there is a need to determine the full scope of these costs.

In regards to the research question concerning the adequacy of the current cost accounting system, it is obvious to DMA management and DOD management that the current system is inadequate. It has been noted that the evaluation of a better system is ongoing at the DOD level and which is beyond the authority of the DMA.

Although the DMA does not have the authority to replace or make major modifications to the existing system, they can endeavor to fully utilize the current capabilities. For instance, the system provides limited cost data on the presently existing JON element of rework because of the discretionary manner in which it is applied by production personnel.

The two elements of scrap and rework have entire quality improvement programs centered around them in some private organizations. Yet in this production-oriented organization there are almost no records of scrap and internal rework. Also, elements such as external rework and reinspection and retest were not fully accounted for and had to be estimated for this study. Yet there is a JON to accumulate costs for defect corrections. The conclusion can be reached that if a defect is corrected then it has to be reinspected and, when applicable, the piece of equipment has to retested.

To expound on the previous answer to the last research question concerning the alternative designs for the COQ model, the first three steps of the twelve step implementation plan provided in Chapter III addressed the use of a cross-functional installation team to develop an initial cost study

and implement a cost of quality measurement system as a prototype. Although all the cost data reflected in the model was derived from the research conducted, there are alternative and additional means and methods such as developing a standard form to be used by indirect personnel to indicate the amount of time devoted to each of the four COQ categories. Another method of gathering more detailed cost data would be the development of a tracking and appraising system for scrap.

Using various methods similar to those mentioned above to augment the current accounting system, the Repair Division can construct their own version of the COQ model. Of course these alternative means of constructing the COQ model for the DMA would be left to the discretion of the COQ study/installation team. The resulting initial study model would probably be considerably different in its amounts and elements of cost than the model in Appendix A if this type of in-house team concept were used.

It is estimated that the long-term benefits received from improved quality would greatly exceed the additional cost of implementing a quality cost measurement and reporting system at the DMA.

D. RECOMMENDATIONS

The first recommendation is that the management of the DMA, or the Maintenance Directorate, initiate their own up-to-date initial study of COQ. This type of study should provide management with a first hand look at their current quality costs instead of relying on the 1993 data used in this study.

The second recommendation is that the DMA place more emphasis on quantifying their suppliers' quality. In Chapter V, the relevance of supplier quality (or lack of quality) is apparent. A major portion of the internal failure costs incurred by the division resulted from supplier problems.

Again, this is an area where TQL concepts should already be in use and a COQ measurement system would provide quantitative measures.

The final recommendation is that the DMA should replace the DMMS. Recommendations made by the Study Team for the Defense Analysis and Studies Office to initiate the tracking of various costs and inventory measures has reemphasized the need for a new system. Hopefully, the DOD will complete their evaluations and select a standard system or authorize the DMA to install a suitable system of their own choosing capable of fulfilling the tracking requirements of the five areas of quality, customer satisfaction, inventory, financial and accounting, and overhead as recommended by the DASO study.

E. QUESTION FOR FUTURE RESEARCH

The question this researcher would like to see answered in relation to this study is, "what automated cost accounting system can be installed by the DMA to replace the aged DMMS and accumulate costs at a level detailed enough to produce the reports required by a COQ measurement system?" Because of the widespread concern for quality, computerized software programs are available from private sector vendors.

APPENDIX A. COST OF QUALITY MODEL

REPAIR DIVISION'S COST OF QUALITY

FISCAL YEAR 1993	1ST QTR	2ND QTR	3RD QTR	4TH QTR	TOTAL
ELEMENTS					
PREVENTION					
Quality Planning	0.00	0.00	0.00	0.00	0
Supplier Reviews	0.00	0.00	0.00	0.00	0
Data Anal & Preventive Action	19838.12	20292.42	19762.40	15825.06	75718
Planning By Other Functions	0.00	0.00	0.00	0.00	0
Development of Measurement & Control Equipment	0.00	0.00	0.00	0.00	0
Training, General	65834.84	67342.50	65583.56	52517.10	251278
Supervision, QC	13634.22	13946.45	13582.18	10876.15	52039
Clerical, QC	10854.14	11102.70	10812.71	8658.45	41428
Staff Services, QC	70360.62	71971.94	70092.07	56127.37	268552
Quality Motivation Programs	42833.07	43813.98	42669.59	34168.37	163485
Quality System Audits	9919.06	10146.21	9881.20	7912.53	37859
Other Prevention Expenses	0.00	0.00	0.00	0.00	0
QI Prototype	26209.17	26809.38	26109.14	20907.32	100035
TQM Training, Indirect	46569.71	47636.20	46391.97	37149.12	177747
TQM Training, Direct	49757.47	50896.95	49567.55	39692.03	189914
TQM Meetings, Indirect	10464.02	10703.65	10424.08	8347.25	39939
Experimental Development	3341.81	3418.34	3329.06	2665.80	12755
Total Prevention Costs	$369,616.24	$378,080.73	$368,205.49	$294,846.54	$1,410,749

APPRAISAL					
Inspection & Test–	0.00	0.00	0.00	0.00	0
Purchased Material	0.00	0.00	0.00	0.00	0
Laboratory Acceptance Testing	2580.96	2640.07	2571.11	2058.86	9851
Depreciation of Capital Equip	443307.93	453460.02	441615.92	353631.14	1692015
Appraisal Support/Inspection	175901.82	179930.11	175230.44	140318.63	671381
Training, Inspection &					
Test Personnel	0.00	0.00	0.00	0.00	0
Testing	20711.10	21185.40	20632.05	16521.45	79050
Cal & Metrology Support	0.00	0.00	0.00	0.00	0
Set–up of Inspection & Test	0.00	0.00	0.00	0.00	0
Process & Product Audits	49595.81	50731.60	49406.52	39563.07	189297
Checking Labor	0.00	0.00	0.00	0.00	0
Inspection & Test Material	915.69	936.66	912.20	730.45	3495
Receiving Inspections	0.00	0.00	0.00	0.00	0
Preinduction Inspections	0.00	0.00	0.00	0.00	0
Nondestructive Test Inspections	0.00	0.00	0.00	0.00	0
Personnel Qualification	0.00	0.00	0.00	0.00	0
Review Test & Inspection Data	0.00	0.00	0.00	0.00	0
Field Testing & Inspection	0.00	0.00	0.00	0.00	0
Accumulation of Cost Data	0.00	0.00	0.00	0.00	0
FMF Equip Evaluations	3920.83	4010.62	3905.87	3127.69	14965
Travel, Admin	27209.75	27832.87	27105.89	21705.49	103854
Surveys	726.53	743.16	723.75	579.56	2773
Total Appraisal Costs	**$724,870.42**	**$741,470.51**	**$722,103.74**	**$578,236.33**	**$2,766,681**
INTERNAL FAILURE					
Scrap (Sale of Scrap)	29346.10	30018.14	29234.09	23409.67	112008
Rework -- Division	0.00	0.00	0.00	0.00	0
Supplier Caused Losses,					
Shipment Shortages	1518.55	1553.33	1512.76	1211.36	5796
RODS/Credit Denied	51660.37	52843.44	51463.20	41209.99	197177
Loss Shipments	2651.70	2712.43	2641.58	2115.29	10121
Price Variances	117765.59	120462.52	117316.11	93942.78	449487

Rework of Supplier Rejects	0.00	0.00	0.00	0.00	0
Improvement Teams	11346.17	11606.01	11302.87	9050.95	43306
Quality Circles	0.00	0.00	0.00	0.00	0
Accidents and Injuries	237596.27	243037.41	236689.42	189532.90	906856
Absenteeism	0.00	0.00	0.00	0.00	0
Loss of Billing Discounts	0.00	0.00	0.00	0.00	0
Troubleshooting	0.00	0.00	0.00	0.00	0
Retest and Reinspection	175901.82	179930.11	175230.44	140318.63	671381
Remedial Engineering	0.00	0.00	0.00	0.00	0
Substandard Product Costs	0.00	0.00	0.00	0.00	0
Shop down Time, General Delays	1324.15	1354.47	1319.09	1056.29	5054
Awaiting Materials	538.67	551.01	536.62	429.70	2056
Extra Production Operations	0.00	0.00	0.00	0.00	0
Defect Correction	23728.55	24271.96	23637.99	18928.50	90567
Labor Adjustment	26678.94	27289.90	26577.11	21282.05	101828
Total Internal Failure Costs	**$680,056.89**	**$695,630.72**	**$677,461.26**	**$542,488.13**	**$2,595,637**
EXTERNAL FAILURE					
Warranty Work	1888.50	1931.74	1881.29	1506.47	7208
Returned Product Costs	0.00	0.00	0.00	0.00	0
Field Service and Travel	18782.26	19212.38	18710.57	14982.79	71688
Rework, Contact Teams	1255.77	1284.52	1250.97	1001.74	4793
Reinspection/Retest	46907.17	47981.38	46728.14	37418.31	179035
Complaint Investigation & Customer Service	10922.78	11172.92	10881.09	8713.21	41690
Recall Costs	0.00	0.00	0.00	0.00	0
Return Costs	0.00	0.00	0.00	0.00	0
Total External Costs	**$79,756.47**	**$81,582.95**	**$79,452.05**	**$63,622.53**	**$304,414**
TOTAL QUALITY COSTS	1854300.02	1896764.91	1847222.54	1479193.53	$7,077,481

APPENDIX B. STATISTICAL DATA AND MEASUREMENT BASES

This appendix presents the statistical data and measurement bases used in the calculations presented in the body of the thesis.

STATISTICS					
1. Total Revenue	14188692	15760664	15170737	22596734	67716827
2. Factory Hours	368456	405433	402728	392124	1568741
3. Cost of Units Produced (Total Op Costs)	21039948	22907582	23065932	19887479	86900941
4. Total Units Produced	10336	16381	12282	15887	54886
5. Direct Labor per Hour	57.1	56.5	57.27	50.72	55.4
6. Inspections (Does not include Receiving, Preinduction, or Nondestructive Testing)	26528	40038	27476	34201	128243
7. Defects, Major	480	1056	557	572	2665
8. Defects, Minor	319	754	4938	4707	10718

BASES					
1. Internal Failure\Direct Labor	0.032	0.030	0.029	0.027	0.030
2. Total Failure\Cost of Units Produced	0.036	0.034	0.033	0.030	0.033
3. Test & Inspection Costs per Unit Produced	19.11	12.33	16.02	9.92	13.74
4. Total QC\Total Revenue	0.131	0.120	0.122	0.065	0.105
5. Prevention\Total Revenue	0.026	0.024	0.024	0.013	0.021
6. Appraisal\Total Revenue	0.051	0.047	0.048	0.026	0.041
7. Internal Failure\Total Rev	0.048	0.044	0.045	0.024	0.038
8. External Failure\Total Rev	0.006	0.005	0.005	0.003	0.004
9. Total QC\Cost of Units Produced	0.088	0.083	0.080	0.074	0.081

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